Association between Prehospital Emergency Care (PEC) Factors and Traumatic Brain Injury (TBI) Mortality in Kiambu and Nairobi Counties, Kenya

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A Thesis Submitted in Fulfillment of the Requirements for the Award of the Degree of Doctor of Philosophy in Public Health in the Department of Public and Global Health

University of Nairobi

June 2023

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

I dedicate this study to God, who has granted me divine help, energy, and the ability to complete all the requirements. I also dedicate it to my dear spouse, Ms. Maureen Kinyua, and our Son, Angel Abner for their unquantifiable moral, spiritual, and emotional support throughout the study phases to its completion.

ACKNOWLEDGEMENT

The completion of this thesis is the culmination of remarkable support and sacrifice by multiple resource persons and institutions. They have helped me overcome the overwhelming yet dynamic and ever-changing challenges faced during the course of this study. I am eternally grateful to God for his divine help in the completion of this study.

I am exceedingly grateful to my supervisors, Dr. Faith Thuita and Dr. Vincent Okungu, for their exceptional support and guidance in this study. Their dedication, commitment, and subject matter expertise have been invaluable to the soundness and robustness of the evidence presented.

I am very indebted to my former supervisors, Dr. Martin Atela and Dr. Thaddaeus Egondi, for their outstanding supervision, moral support, and mentorship. Their scientific footprints will forever be a part of my scholarly history. Many thanks to Prof. Joseph Wangombe, Dr. Marshal Mweu, and Dr. Richard Ayah, who made invaluable expert contributions and provided support at different stages of this study. I appreciate the remarkable leadership and encouragement of Professor Joyce Olenja and Prof. Mutuku Mwanthi for their exceptional patience, kindness, and caring values. I am greatly thankful to the entire departmental staff, in particular, Ms. Esther Chogo and Kenneth Owuori, for their unparalleled support.

I am indebted to my student colleagues, particularly George Ogot and Kellen Karimi, who constantly inspired and encouraged me to work towards the completion of this study. Many thanks to my research assistants, Mr. Martin Mwenda, Mr. Bonface Muthomi, Ms. Faith Ngatia, Mr. Seth Muchui, and Ms. Winfred Kananu, for their technical and logistical contributions. I am equally indebted to my university work colleagues, including Dean, Mr. Peter Mwaura, for their sustained support, peer review, and encouragement throughout this study period.

Many thanks to the Higher Education Loan Board (HELB) for funding the tuition fees for this PhD course. The scholarship has been instrumental in focusing my time, energy, and commitment on the study. Many thanks to the management of the various hospitals, counties, and institutions in which this study was undertaken. Sincere appreciation to all the direct and indirect study participants.

Above all, I express my heart-felt gratitude to my family for their moral, spiritual, and emotional support throughout my scholarly journey. In particular, I am forever indebted to my spouse, Ms. Maureen Kinyua and our son, Angel Abner, for their unwavering and immeasurable moral and spiritual support.

God bless you all.

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LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
ALS	Advanced Life Support
AMREF	African Medical and Research Foundation
BLS	Basic Life Support
CI	Confidence Interval
CNS	Central Nervous System
CT	Computerized Tomography
DALYs	Disability Adjusted Life Years
ED	Emergency Department
EMS	Emergency Medical Services
ERC	Ethical Review Committee
ETI	Endotracheal Intubation
GCS	Glasgow Coma Scale
HIV	Human Immunodeficiency Virus
ICUs	Intensive Care Unit
IRB	Institutional Review Board
ISS	Injury Severity Score
IVs	Intravenous Fluids
KHSSP	Kenya Health Sector Strategic Plan
KII	Key Informant Interview
KNH	Kenyatta National Hospital
LMICs	Low- and Medium-Income Countries
MoH	Ministry of Health

NGO	Non-Governmental Organization
NHIF	National Hospital Insurance Fund
NTSA	National Transport and Safety Authority
OR	Odds Ratio
PEC	Prehospital Emergency Care
PHC	Primary Health Care
PI	Principal Investigator
POM	Proportional Odds Model
PPOM	Partial Proportional Odds Model
RCS	Red Cross Society (of Kenya)
RTA	Road Traffic Accident
SDG	Sustainable Development Goal
TBI	Traumatic Brain Injury
TI	Traumatic Injury
UHC	Universal Health Coverage
UK	United Kingdom
UoN	University of Nairobi
US	United States
USD	United State Dollars
WHA	World Health Assembly
WHO	World Health Organization

DEFINITION OF TERMS

Ambulance Transport	Ambulance transport comprises patient transport to a tertiary care facility using an ambulance, while non-ambulance transport comprises all other forms of non-ambulance transport such as private vehicles, public vehicles, walk-ins, portable carts, and police transport, among others.
An Emergency Medical Dispatch	Refers to a professional telecommunication process in which a professional call dispatcher is tasked with gathering medical emergency information from the scene, providing assistance or instructions by voice, and dis patching emergency medical services (EMS) resources responding to the emergency call.
Prehospital Time	This refers to the total time taken for a trauma patient to be transported (evacuated) from the injury scene to a trauma level 1 facility or specialized trauma care facility for treatment and care after injury.
Burden of Trauma	Refers to the magnitude of trauma-related mortalities, disabilities, and complications in a population.
Casualty	This is a person who is killed, wounded, or injured by some event such as an accident.
Casualty Characteristics	This refers to the physiological and anatomical status of the trauma patient.

Emergency Care System (ECS)	This is care that extends from care at the scene through transport and emergency unit care, and to early operative and critical care when needed.
Emergency Medical Services (EMS)	These are services dedicated to providing out-of-hospital acute medical care and transport to definitive care for patients with illnesses and injuries which prevent them from transporting themselves.
Emergency Medicine Specialist	Refers to a medical doctor who specializes in emergency medicine practice through the diagnosis and treatment of medical emergencies.
Glasgow Outcome Scale (GOS)	This is a functional trauma outcome measure that categorizes patients with traumatic brain injuries (TBI) into five levels: Dead, Vegetative State, Severe Disability, Moderate Disability, and Good Recovery.
Health System	According to the World Health Organization (WHO, 2010), a health system is defined as the organization of people, institutions, and actions whose primary intent is to promote, restore, or maintain health and health outcomes. In this study, EMS transport or evacuation response, pre-hospital interventions, pre-hospital care providers, and health financing have been selected as fundamental factors of a health system to be studied. This is in addition to studying other contextual factors of pre-hospital care delivery, which includes leadership, information management, and medical supplies and equipment required for optimal care.

Health System Capacity	This is the design, resource, and operational capabilities of the system to respond and meet population health needs.
Lay Responders	These are bystanders composed of community members and eyewitnesses at the scene of injury who have no basic skills in the provision of first aid.
Major Trauma	This is either penetrating and/or blunt injury with the potential to cause prolonged disability or death denoted with a Glasgow Coma Scale (GCS) score of ≤8.
Over triaged Patients	Over-triaging comprises those patients who are not severely injured but were given higher severity scores and/or receiving prioritized life-saving interventions meant for severely injured patients.
Patient Functional Outcomes	This is a measure index of functional outcome that rates patient status and/or recovery into one of five categories following major traumatic injury. The five categories are Dead, Vegetative State, Severe Disability, Moderate Disability, or Good Recovery.
Prehospital Deaths	These are deaths occurring between the scene of an injury and before arrival at the hospital.
Prehospital Emergency Care (PEC)	Refers to the life-saving emergency rescue services (including life-saving services such as airway support, bleeding control, etc.) given to an injured patient using an ambulance by a qualified health professional such as a paramedic, clinician, or nurse in the out-of-

	hospital settings and before admission at the Accident and Emergency Department of a specialized Trauma Care Facility.
Pre-hospital Medical Care Interventions	This refers to the life-support treatments, procedures, and services offered to the patient before arrival at the hospital.
Prehospital Referral Pathway	This refers to the patient transfer trail from the scene of injury up to the specialized trauma facility in which the patient is admitted or managed. The pathway comprises direct and indirect referral pathways. Direct referral refers to the direct transfer of patients from the injury scene to a specialized trauma care facility, while indirect referral refers to the transfer of casualties to a specialized trauma care facility through lower trauma facilities, also known as peripheral facilities.
Trauma Triage	Trauma triage is the use of trauma assessment for prioritizing patients for treatment or transport according to their severity of injury at the site of injury and again at the receiving hospital. Three triage levels were included in this study; not-urgent, which designates no to minor injury; urgent, which designates moderately injured patients; and very urgent or emergency cases, which designate severely injured patients requiring immediate emergency medical care attention.

Prevalence of Major Trauma	This refers to the number of major trauma injuries documented within the study period divided by the number of injuries recorded within the period, expressed as a percentage.
Professional Pre-hospital Care	This is pre-hospital care provided by trained healthcare providers. The care includes the use of equipped ambulances.
Prehospital Emergency Care Providers	These comprise the various healthcare providers trained to provide professional pre-hospital care to trauma patients, including paramedics, EMS technicians, physicians, and other trained lay responders.
Quality of Trauma Care	This is the adequate implementation of the minimum standards and interventions confirmed to be affordable, safe, and able to cause a positive impact on morbidity, mortality, and disability outcomes of a patient.
Trauma	This is a body wound or shock produced by a sudden physical injury.
Trauma Epidemiology	This is the study and analysis of causes, patterns, and distribution of trauma in different populations.
Trauma System	This is an organized effort in a defined geographic area that delivers the full range of care to injured patients.
Traumatic Brain Injury (TBI)	This is a brain dysfunction or non-congenital insult caused by a violent external force or blow to the head.

Under-triaged Patients	Refer to patients with severe injuries who are given a non-urgent triage status in the prehospital settings and/or are not managed by a skilled responder capable of triaging the patient using recommended criteria.

PAPERS PUBLISHED FROM THIS THESIS

1. **Health system factors associated with post-trauma mortality at the prehospital care level in Africa: a scoping review**

   Koome G, Atela M, Thuita F *and* Egondi T. (2021). Health system factors associated with post-trauma mortality at the prehospital care level in Africa: a scoping review. *Trauma Surgery & Acute Care Open*; **5:** e000530. (doi: 10.1136/tsaco-2020-000530)

2. **Association between traumatic brain injury (TBI) patterns and mortality: a retrospective case-control study**

   Koome G, Thuita F, Egondi T and Atela M. (2022). Association between traumatic brain injury (TBI) patterns and mortality: a retrospective case-control study. *F1000Research*, **10**:795. (https://doi.org/10.12688/f1000research.54658.2)

ABSTRACT

Background: Traumatic Brain Injury (TBI) is a major cause of trauma burden, accounting for over 69 million injuries globally. Low- and middle-income countries (LMICs) account for approximately three times the burden of TBIs compared to High-Income Countries (HIC). This significant burden is primarily attributed to the weak capacity of prehospital emergency care (PEC) systems in LMICs. In Kenya, all forms of trauma, including TBIs, have become a leading cause of death. Many of these avoidable deaths are due to delays in accessing quality PEC. However, there is limited local evidence to guide evidence-based life-saving interventions at this level of care.

Objective: The objective of this study was to determine the association between PEC system factors and traumatic brain injury mortality in Kiambu and Nairobi counties, Kenya.

Methods: A retrospective case-control study was conducted with a sample of 316 TBI patients comprising 158 cases and 158 controls. The cases and controls were randomly selected using an Excel list. Data was abstracted from patient medical records for the period of January 2017 to March 2019 from three tertiary trauma care facilities in Kenya. A logit model was used to analyze the association between PEC factors and TBI mortality, while adjusting for patient characteristics and other potential confounders. Qualitative data from 38 purposively sampled key informants were thematically analyzed to complement the quantitative data using the convergent triangulation method.

Results: The study population was predominantly youthful with 73%, of the patients being under 40 years old, and mainly males. Road traffic injuries (RTIs) accounted for 58% of all forms of trauma patterns, with blunt trauma comprising 71% of the injuries. More than half (58%) of the patients did not access PEC, while nearly three-quarters (75%) were transferred directly to a tertiary trauma hospital. Female gender (*OR=2.65; 95%CI: 1.19-5.92; P=.017*);

severe trauma (GCS 13-15) (*OR=4.00; 95%CI: 2.10-7.66; P=.001*); under-triaging emergency cases (*OR=3.01; 95%CI: 1.46-6.24; P=.003*); hypoxemia (*OR=5.95; 95%CI: 3.09-11.45; P=.001*), and comorbidity (*OR=1.27; 95%CI: 0.81-5.26; P=.041*) were significantly associated with an increased risk of TBI mortality.

The type of trauma mechanism (RTI) and type of injury (blunt trauma) were also significantly associated with mortality. The risk of death for patients sustaining RTIs was 2.83 times higher compared to non-RTI patients [*OR=2.83, 95% CI; 1.62-4.93, p=0.001*], while sustaining blunt trauma had a 1.23 times higher risk of TBI mortality compared to sustaining penetrating trauma (*OR=1.23; 95%CI: 1.01-1.50; P=.044*).

Access to PEC (*OR=0.52; 95%CI: 0.03-9.32; P=.659*) and the type of patient transfer system used (direct transfer to a tertiary hospital) (*OR=1.49; 95%CI:* 0.27-8.20*; P=.659*) were not significantly associated with TBI mortality. However, transferring patients to a tertiary public facility was associated with a 2.82 times higher risk of death compared to a private facility (*OR=2.82; 95%CI: 1.51-5.29; P=.001*). Gaps in the PEC system include, access to few ill-equipped ambulances, lack of dedicated trauma calls or coordination centers, patient mishandling by untrained lay rescuers, absence of relevant policy frameworks, weak governance structures, and weak critical trauma care capacity in public primary health facilities among others.

Conclusion: In traumatic brain injuries (TBIs), various patient characteristics such as gender, trauma severity, triaging ranks, and oxygen concentration levels (presence of hypoxemia) are crucial in designing and implementing locally responsive TBI life-saving protocols at the prehospital emergency care (PEC) level. Road Traffic Injuries (RTIs) significantly contribute to the mortality burden associated with TBIs in Kenya. However, access to PEC and the type of patient transfer pathway do not provide any mortality benefits to TBI patients due to inherent

weaknesses in the PEC system's capacity. The main reason for the increased risk of TBI mortality in public trauma care facilities is the lack of critical care capacity.

To address the identified gaps at the PEC level, it is recommended to implement the approved Kenya Emergency Medical Care Policy 2020-2030 guidelines on the design, implementation, and management of emergency care services. Specifically, to mitigate TBI risks for patients, the study suggests several priority interventions at the PEC level: (i) Review, enhance capacity, and expand the use of gender-sensitive Glasgow Coma Scale (GCS) as a triaging protocol for TBI responses, (ii) Scale-up training programs for TBI triaging and diagnostic capacity, and (iii) Improve the supply and training related to oxygen supplementation. To mitigate TBI risks associated with RTIs, the study recommends the development and adoption of a RTI risks map that shows risk profiles, which can support public trauma sensitization campaigns. Additionally, it suggests supporting effective coordination between ambulance services and dispatch centers, connected to well-equipped facilities. To strengthen the capacity of Emergency Medical Services (EMS) systems, facilities, and infrastructure to deliver quality PEC care, the study recommends; (i) Establishing functional trauma command centers at all levels, both county and national, (ii) Enhancing access to well-staffed, coordinated, and equipped ambulances, (iii) Training and deploying resourced community-based emergency response teams. Finally, to provide advanced critical TBI care along the referral pathway as an extension of PEC, the study recommends strengthening the functional capacity of public hospitals, especially primary facilities.

CHAPTER ONE

INTRODUCTION

1.1 Background to Traumatic Injury and Pre-Hospital Care

1.1.1 Definition of Traumatic Injuries

Traumatic Injury (TI) refers to a sudden onset of severe physical injury that requires immediate medical attention, including resuscitation, airway management, and other life-saving interventions. There are various forms of trauma depending on the injured part of the body, such as traumatic brain injury (TBI), spinal cord injury, facial trauma, and amputation, among others. Traumatic brain injury (TBI) refers to a non-degenerative, non-congenital insult to the brain or brain dysfunction caused by an external mechanical force to the head. This type of injury can result in permanent or temporary impairment of cognitive, physical, and psychosocial functions, accompanied by a diminished or altered state of consciousness.

Traumatic brain injury (TBI) is a significant cause of disability and death, particularly, among individuals under the age of 40 worldwide. Mortality rates among older individuals are also increasing (Dewan et al., 2019). Approximately, 69 million cases of TBIs are reported globally each year, with road traffic injuries (RTIs) being the main cause. Other causes of traumatic injuries include violence, assaults, and falls (Suryanto et al., 2017; Taibo et al., 2016).

1.1.2 Burden of Traumatic Injuries (TBIs)

Traumatic injuries (TIs) are physical injuries of varying severity that require medical attention or intervention. TIs contribute significantly to global disease mortality and morbidity. Worldwide, traumatic injuries are associated with 5.8 million deaths (approximately 10% of global mortality) which is nearly 1.7 times the combined number of deaths from HIV/AIDS,

tuberculosis, and malaria (Edem et al., 2019). The World Health Organization (WHO) (2016) estimates that traumatic injuries account for at least 6% of all Disability-Adjusted Life Years (DALYs) (WHO, 2016). Low and medium-income countries (LMICs), primarily African countries, bear about 90% of the trauma disease burden, including traumatic deaths, trauma mortality, and morbidity (Adeloye, 2012; Obermeyer et al., 2015). For example, in Ghana, the estimated mortality from post-trauma injuries was 13% (Mahama et al., 2018), while in Nigeria, the mortality rate was 40% (Adeloye, 2012).

Worldwide, approximately 1.2 million road traffic injuries (RTIs), a major source of TBIs, occurred in 2012, with males aged 15-29 years being the most affected group (Ladeira et al., 2017). In Ghana, 50% of trauma cases were attributed to traffic-related injuries and falls (Suryanto et al., 2017). The public health burden of RTIs and other traumatic brain injuries remains a growing concern in LMICs, which experience nearly three times more cases of TBIs (Dewan et al., 2019). RTIs are projected to increase by approximately 80% in the next decade due to the rise in motorization, low adherence to road traffic regulations, and the lack of effective emergency medical services (EMS) at the prehospital care level (WHO, 2016). Despite the high burden, LMICs are ill-equipped and lack resources to manage the significant trauma burden, including TBI, in both out-of-hospital and in-hospital settings (Nielsen et al., 2013; Obermeyer et al., 2015; Reynolds et al., 2017; Suryanto et al., 2017).

1.1.3 Prehospital Emergency Care

The Kenya Emergency Medical Care Strategy 2020-2025 defines prehospital care as medical care provided in settings other than a hospital to patients who are planned or intended to be transported to the nearest most appropriate healthcare facility for further care or evaluation (MoH, 2020). In this study, prehospital care is contextualized to mean care provided to trauma

patients before and/or during transport to the hospital by trained emergency medical service [EMS] providers or laypersons, also known as bystanders at the time of the accident.

Within the devolved system of governance upon promulgation of the 2010 constitution in Kenya, health was devolved to the county level with the national and county levels having distinct but interdependent functions. For instance, under the devolved system, the national government is mandated with the provision of suitable health policy and standards, oversight of national referral facilities and system, disaster management, staff capacity building, and technical support including but not limited to EMS policy, training, and provision of specialist trauma care through the network of referral hospitals (MoH, 2013).

The county mandate, on the other hand, revolves around health policy implementation and service delivery, which includes the provision of prehospital EMS through a network of county-managed health facilities and ambulance services. The devolved prehospital function is mainly offered by hospital-based ambulance services run by the county health departments and complemented by the private sector comprising non-profit organizations like E-plus by the Red Cross Society and St. John`s Ambulance, as well as private providers such as Avenue Health Care, Nairobi Hospital, among others.

Prehospital care is an integral part of the EMS and the broader health system that provides a systematic and organized aspect of immediate care to patients at the trauma scene, during transport, and throughout the out-of-hospital period (WHO, 2016). It refers to an all-inclusive organization of well-trained health professionals, institutions, resources, and services providing emergency medical care responses comprising ambulance dispatch, rescue, triaging, stabilization and treatment as well as transport to a definitive care facility for further care/management in the out-of-hospital settings and at the emergency unit of the hospital (MoH, 2013). Despite decades of increasing trauma burdens and related mortalities presented

to health facilities, emergency medicine was only recognized as a profession or specialization in Kenya in June 2017.

One of the outcome measures of prehospital care system performance is post-trauma mortality outcomes. In this study, the term trauma mortality refers to deaths occurring after trauma while prehospital care level refers to post-trauma care provided through out-of-hospital settings where a patient is attended to before successful evacuation and admission in a trauma care facility.

In Kenya and other LMICs, a number of prehospital care challenges have been identified from the health system perspective. These range from limited access to quality prehospital care, few equipped ambulances, a shortage of skilled prehospital care providers, poorly resourced and developed health and social infrastructure, as well as poor leadership and governance structures (Broccoli et al., 2015a; Roy et al., 2017). Generally, the prehospital EMS serves six major functions for prehospital trauma care, namely: response, detection, reporting, on-scene care, care in transit, and transfer to advanced trauma care hospital (Matheka et al., 2015). Due to non-prioritization and weak leadership from the government, the five years of professional practice since recognition in 2017 reflects a discipline yet to fully mature and/or evolve into a respectable practice or function and impact on health outcomes across the country. This is mainly because in Kenya, professional EMS practice is yet to receive appropriate government attention and prioritization in terms of policy, governance, leadership, and resource allocation.

Prehospital care systems in LMICs are reported to be either non-existent or poorly developed. As a result, the greatest proportion of trauma burden in low-resource countries is attributed to a lack of or limited access to quality emergency care and delays to advanced critical care in the pre-hospital settings (Gathecha et al., 2017). A large proportion of this burden is potentially preventable through quality time-sensitive life-saving interventions (Adeloye, 2012; Oliver et

al., 2017a). For instance, in the United Kingdom (UK), which is a high-income country (HIC), more than half (54%) of pre-hospital trauma deaths have been categorized as potentially preventable (Oliver et al., 2017a). In some parts of Africa, e.g., South Africa, (an upper middle-income country) reported preventable mortality is as high as 70% (Edem et al., 2019), 60% in Ghana (Yeboah et al., 2014), and 30% in Nigeria (Adeloye, 2012). This suggests higher value-add for effective and quality pre-hospital EMS care in LMICs and, in particular, within African settings.

Integrated emergency prehospital care, also known as Emergency Medical Services (EMS), is a fundamental component of an effective health system for providing quality and effective prehospital life-saving responses in the out-of-hospital care settings. In the prehospital emergency care system, an efficient transport or evacuation system, trained healthcare professionals, access to prehospital life-saving interventions, and effective referral pathways comprise core elements of the prehospital care system. Combined, these factors constitute critical elements that may substantially contribute to the provision of organized and effective EMS at this level of care targeting acute traumatic conditions such as TBIs. Understanding the traumatic patterns for these conditions can better help inform adaptation of the response to the uniqueness of the injuries sustained. A snapshot of empirical evidence on the role of these emergency prehospital care factors on traumatic mortality outcomes at this level of care is described in the upcoming sections.

1.1.3.1 Access to prehospital care: In the context of weak prehospital care systems in many LMICs, the timely provision of quality care or life-saving interventions at the prehospital care level remains a key priority in improving post-trauma survival. Some studies recommend timely initiation of interventions at the injury scene and en route to the hospital in line with the "golden hour" or the 60-minute concept - a critical time-period for successful life-saving or

care intervention (Curtis et al., 2016; Lerner and Moscati, 2001; Pham et al., 2017). The golden hour concept seeks to prevent avoidable time-sensitive complications associated with irreversible pharmacological changes in the patient's body (Lerner and Moscati, 2001; Lyon et al., 2015; Newgard et al., 2010). However, there is limited evidence in the literature regarding the effect of the golden hour concept on TBI mortality outcomes.

The provision of Basic Life Support (BLS) interventions to trauma patients has been extensively recommended in the prehospital care setup (Taibo et al., 2016). There are two prehospital care interventions that can be provided at the prehospital care level by trained care providers: Basic Life Support (BLS) and Advanced Life Support (ALS) (Sanghavi et al., 2015). BLS involves providing adequate ventilation, oxygenation, and securing the airway (Thompson et al., 2017b). In most cases, prehospital deaths occur as a result of uncontrolled hemorrhage, respiratory failure, and airway compromise or obstruction, which comprise the BLS service package. Developed countries have integrated the use of ALS interventions in prehospital care, which is rare in developing countries such as Kenya.

Advanced Life Support (ALS) is defined as a set of skills and life-saving protocols that extend Basic Life Support to further provide adequate breathing (ventilation), an open airway, and enable circulation, such as rapid sequence induction, endotracheal intubation (ETI), cardiac defibrillation, cardiac monitoring, transcutaneous pacing, chest tube insertion, intravenous fluids (IVs), and anesthesia induction, among others. However, few patients receive BLS at the prehospital care level, with most trauma victims receiving no interventions due to a lack of qualified medical practitioners and evacuation facilities in these settings (Gathecha et al., 2017). Without well-trained medical providers such as paramedics, emergency medical technicians, qualified bystanders, and supportive service delivery systems such as medical supplies, ambulances, and coordination functions, access to these services remains idealistic.

1.1.3.2 Means of transport or evacuation: An efficient and prompt prehospital evacuation or transport of trauma patients to a care facility can be an important determinant of post-trauma care outcomes (Sanghavi et al., 2015). A study by Georgiou and Lockey suggests that prompt transport of patients with proper care, from the scene of injury to specialized trauma centers, can significantly increase survival (Georgiou and Lockey, 2010). It is estimated that about half of the traumatic deaths occur due to prehospital delays (Suryanto et al., 2017). In many LMICs, more than half of trauma patients are transported in non-ambulatory vehicles without proper handling capacity and skilled personnel to provide life-saving interventions (McCoy et al., 2013a; Zafar et al., 2014).

Inadequate prehospital evacuation, limited skilled providers for critical trauma care, and poor coordination and leadership (Mehmood et al., 2018; Raj et al., 2013; Reynolds et al., 2012) have led to the provision of prehospital transport by unskilled lay responders and inadequately resourced private and non-governmental organizations (NGOs) to a huge number of vulnerable populations. The effect of these health system interventions on TBI mortality outcomes is not well-documented, and the existing evidence is both scanty and mixed to aid a reliable conclusion on their utility value or benefits (Suriyawongpaisal et al., 2014; WHO, 2016). In Kenya and other resource-scarce contexts in Africa, where evacuation time often exceeds the recommended 50 minutes, there is limited scientific evidence on the effect of these life-saving interventions on TBI mortality outcomes. Therefore, advocacy for the golden hour exists as an ideal concept rather than a practical concept that can be used as a benchmark.

Generating evidence on the efficacy and contribution of life-saving interventions or prehospital care, including prehospital transport modes, on TBI mortality outcomes is crucial in defining the best policy and programmatic pathway to building a resilient prehospital care system for TBI responses in the country.

1.1.3.3 Trained EMS Providers: In an out-of-hospital setting, paramedics are trained to provide either Basic Life Support (BLS) and/or Advanced Life Support (ALS) for trauma patients (Calvello et al., 2013a). Kenya has continually trained EMS providers, but they are not recognized as part of the mainstream healthcare providers and are rarely deployed to provide critical emergency care in these settings. In high-income countries, a prehospital chain of survival in cardiac arrest, acute stroke, and trauma care has demonstrated the critical role of prehospital care in improving trauma-related mortality (Van et al., 2016). In many LMICs, the lack of effective prehospital care responses has been argued to contribute to poor trauma outcomes and increasing trauma burden compared to high-income countries (Mould-Millman et al., 2013; Obermeyer et al., 2015).

1.1.3.4 Referral Pathway: Patient referral pathways also play a fundamental role in mortality outcomes. According to Boschini et al. (2016), direct transfer or referral of trauma patients from the scene to the trauma center may confer a survival advantage by reducing the time spent on referrals from peripheral hospitals. While this indirectly supports the value of the golden hour and ambulance transport in trauma distress responses, other studies refute this finding due to a lack of reliable evidence (Balikuddembe et al., 2017; Möller et al., 2018; Williams et al., 2013). As a result, the concept of the "golden hour-60-minute concept" remains a controversial subject in terms of the benefits of care outcomes in both developed and developing countries.

At the injury scene in low-resource countries, trauma patients are less likely to receive any basic life support care, such as first aid care, and are often transferred to the nearest hospital by untrained lay responders (Balikuddembe et al., 2017; Boschini et al., 2016; Mehmood et al., 2018). In this study, we included lay responders, also known as "no care" to refer to many patients who are not attended to by a trained care provider at the prehospital care level. In this setting, the type of referral pathway and its role in mortality outcomes may vary depending on

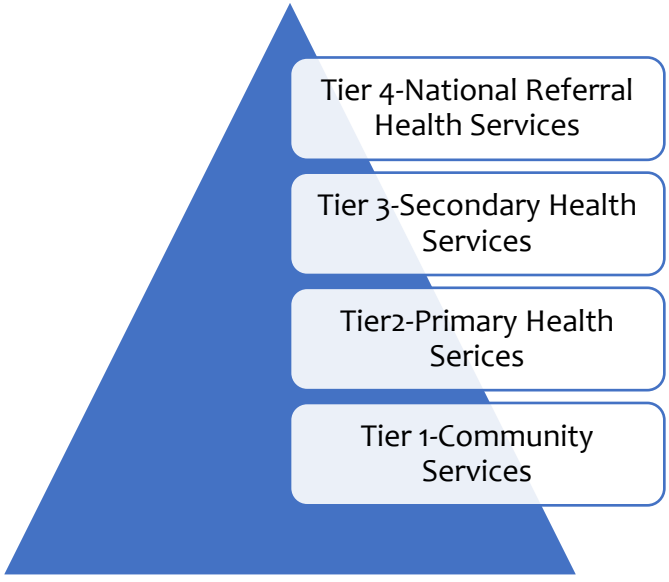
contextual factors, including access to trained providers, the quality of ambulatory evacuation, the quality of the facility providing definitive critical care, and the supportive infrastructure – both transport and healthcare. Conducting further analysis on the role of the referral pathway in post-trauma mortality outcomes can offer valuable insight into the prehospital care reform agenda in the country.

1.2 Status of Prehospital Emergency Medical Services (EMS) Care in Kenya

1.2.1 Kenyan Health System Structure and Estimated Number of Facilities

Under the 2010 constitutional dispensation, the Kenyan health system was organized into four tiers of care in line with the Kenya Essential Package of Health (Republic of Kenya, 2013). In Figure 1, specialized facilities providing advanced critical trauma care and management are positioned at the top of the pyramid. The number of estimated facilities for each tier is indicated.

Figure 1: Health System Structure



Source: (MoH, 2013)

The first tier of the health system structure is composed of community health workers and volunteers supervised by community health extension workers. Their main responsibilities include identifying illnesses at the household level, treating minor ailments, and initiating referrals to higher levels of the health system (community services). The community services network is organized and delivered within the community, and it consists of functional community health units and semi-functional community health units.

The second tier comprises primary care facilities, which include dispensaries and health centers. These facilities are staffed by nurses and clinical officers who provide general outpatient services, antenatal monitoring, and perform minor surgical procedures. The estimated number of primary care facilities is 9502, which consists of 5113 dispensaries, 3030 clinics, 932 health centers, 106 maternity homes, and 321 nursing homes. Approximately 38% of these facilities are privately owned, while faith-based facilities comprise about 10% of the total number (Table 1).

Table 1: Kenyan Health System Organization Structure

Facility Category	**Tier Structure**	**Type of services provided**	**Number of Facilities per tier**
National and large private teaching and referral hospital	Tier 4	Tertiary /specialized health services	16; Private hospitals: 75% (16)
County Hospitals which comprise county referral, medium-sized hospitals and sub-county hospitals	Tier 3	Secondary Health Services	541; Private:26% (140); Faith Based (FB):15% (81)

Facility Category	Tier Structure	Type of services provided	Number of Facilities per tier
Health Centers and Dispensaries	Tier 2	Primary Care Health Services	Primary Care Facilities; Private: 38% (3144); FB: 10% (827)
Community Services	Tier 1	Community Care Services	

Source: Master Facility List, MoH, 2021.

The third tier is comprised of approximately 541 county referral and sub-county public hospitals, as well as other medium-sized private hospitals. These facilities are primarily staffed with nurses, clinical officers, and a few medical officers. Within this tier, private facilities account for approximately 26%, while FB facilities make up about 15%. Some of these facilities, particularly county referral hospitals and medium-sized private hospitals, also serve as training centers for clinical officers and nurses, as well as internship centers that provide critical trauma services. However, it is worth noting that clinical officers, medical doctors, and nurses working in county-level referral hospitals (both private and public) reportedly have limited training in critical trauma care and management, including resuscitation and stabilization. This represents a significant gap in the provision of quality trauma care (Broccoli et al., 2015a).

The fourth tier consists of national-level hospitals, including around 16 national referral and teaching facilities, with a distribution of approximately 75% private and 25% public. These hospitals specialize in highly specialized care, such as trauma care, and also serve as training and research support centers. However, access to emergency care specialists in national referral and teaching hospitals is limited (WHO, 2017a). The majority of these facilities are staffed

with nurses, medical officers, and other consultants who have received training in emergency care, but lack the presence of dedicated emergency care specialists.

Private and FB facilities make up a significant proportion of Kenya's health facilities. More than one-third of private facilities are located in Nairobi Metropolitan (31%) and Mombasa (6%) counties (Solomon and Alley, 2016). This distribution highlights the inequities and inequalities in the accessibility and distribution of emergency care services.

1.2.2 Systemic Gaps in the Prehospital Care System

The majority of TBI patients seek initial emergency care visits in tier one and two facilities. However, these facilities do not have the requisite capacity to provide critical trauma care expected in line with service delivery norms and standards. Due to this capacity gap, many critical trauma care patients who can be managed in these facilities are transferred to higher-level facilities, leading to overcrowding and delayed care.

Primary and secondary care facilities are inadequately resourced with the requisite trauma care skills, resources, and capacity to provide quality emergency care interventions for traumatic conditions such as TBI (Brown et al., 2016; Nielsen et al., 2013). Furthermore, these facilities suffer from ineffective referral and monitoring systems, inefficient trauma response communication and transport systems, low and inadequate financing, lack of digital integration of electronic patient records to inform prompt decisions, and poor inter-facility coordination to aid in efficient and prompt inter-facility referrals for critical patients. The lack of effective and efficient inter-facility communication and coordination limits survival benefits accruable from functional inter-facility linkages, which promotes the integration of the continuum of care along the different care levels within the referral structure (Republic of Kenya, 2013; Wright, 2015).

The Ministry of Health (MOH) indicates that continuity of care across the different tiers depends on a well-functioning referral system, strong linkages across the service delivery tiers, and adequately resourced facilities in line with facility-level service standards and norms (MoH, 2013). Consequently, the Kenya Health Policy 2012–2030 has identified the need to strengthen the referral system in Kenya, which experiences inadequate coordination from the different tiers, as a way of improving efficiency in the health system and improving patient outcomes. The key priority areas for KHSSP II 2012–2018 and the current KHSSP 2018-2023 (MoH, 2018) are to strengthen the referral systems, including for trauma care, across the tiers (Republic of Kenya, 2013). Other critical investment priorities for the referral system outlined in the plan include the provision of updated referral tools and guidelines at all levels, orientation of the management teams on their referral roles and functions, and tools for referral allowances for expertise movement and fuel for travel.

The referral reforms mentioned above are anticipated to enable acute trauma patients, including TBI patients, to be comprehensively managed while optimizing resources and outcomes across all levels of care. The ultimate goal of the Kenya Health Sector Referral Strategy (2014-2018) is to strengthen referral linkages across the tiers of care for efficient health service delivery, with a view to improving the efficiency and patient outcomes of the health system, as outlined in the Kenya Health Policy 2014–2030 and KHSSP 2012–2018 (Republic of Kenya, 2013, 2014). This study seeks to examine the role of different prehospital care referral systems on TBI mortality outcomes, identify existing gaps, and make potential policy recommendations for improvement.

1.2.3 Evolution of Prehospital Emergency Medical Services (EMS) in Kenya

Emergency Medical Services (EMS) is the planned configuration of community resources and personnel necessary to provide immediate medical care to patients with sudden or unexpected illness or injury (Mould-Millman et al., 2015). EMS incorporates rapid assessment, timely provision of appropriate interventions, and prompt transportation to the nearest appropriate health facility by the best possible means to enhance survival, control morbidity, and prevent disability.

The initiation and development of EMS in Kenya was spurred by a mass disaster that occurred on August 7, 1998, through a truck bomb explosion at the U.S Embassy in Nairobi, which killed around 240 people while injuring over 5,000 others (Martin, 2011; Thompson, 2013). At this time, there were no trained emergency responders and Emergency Medical Technicians (EMTs) to offer emergency response and triage at the scene, leading to high morbidity and mortality from the disaster. To mitigate similar incidents, Kenya received $40 million dollars from the United States Agency for International Development (USAID) to develop disaster preparedness systems and strengthen casualty programs (Thompson, 2013). The funding led to the training and graduation of the first EMT class. However, the funding was discontinued in 2002, which slowed down the reform agenda and process. The trained EMTs, however, took it upon themselves to further the development of emergency medical services.

1.2.4 Challenges and Gaps in the evolution of PEC system in Kenya

1.2.4.1 Training and Regulation in PEC

Over time, many emergency training institutions and agencies have evolved, with each individual institution defining the breadth and scope of training content without any formal regulations. Each institution had adopted its own training and practice standards (Thompson,

2013; Wachira et al., 2012). For example, over the last two decades, separate unregulated EMS training programs have been offered by different institutions in Kenya using different and unharmonized curricula: the Kenya Red Cross Training School, St. John Ambulance, and the Kenya Council of Emergency Medical Technicians.

Generating scientific evidence on the quality and effect of the different levels of professional competence on trauma mortality outcomes resulting from the multiple unharmonized training programs can help inform advocacy for a harmonized or standardized EMS training. However, this study doesn't include this scope of evidence. A lack of a national overarching EMS legislation and policy is the main cause of the variation in EMS training and certification standards (Nicholson et al., 2017).

1.2.4.2 Staffing in PEC

Skilled EMS capacity is an essential component of quality prehospital interventions across the service delivery levels (Naughton et al., 2014). To contribute to the national sustainable development goals for healthy and prosperous populations, the health care system does not only require financial capability but also equitable distribution of staff to match the population's critical trauma care needs. The shortage of trained health and, in particular, specialists trained to provide critical care, is high in the country. The available ones are unevenly distributed across counties, resulting in inequalities in the quality and availability of specialized trauma care services. The scarcity of healthcare practitioners remains a weighty factor hindering the provision of quality prehospital and trauma care in line with national development goals for a prosperous nation, including access to equitable and quality emergency care services (Naughton et al., 2014; Status and Professionals, 2015).

For instance, in 2020, Kenya had about 12,792 registered medical officers registered by the Kenya Medical Practitioners and Dentist Board (Julia, 2022). There are also about 1,200

trained EMTs and 300 surgeons based on the Surgeon Society of Kenya report (Ezekiel, 2022) spread throughout the country, albeit inequitably (Naughton et al., 2014; Status and Professionals, 2015). Despite an increasing number of medical practitioners who can be potentially trained in emergency trauma care, there are countable emergency medicine (EM) specialists in the country amid the high burden of potentially preventable trauma mortality requiring specialist skills, knowledge, and expertise to mitigate. This reflects critical skill deficits at the PEC and hospital levels, especially in primary health facilities due to skilled staffing gaps.

The availability of trained health workers, including paramedics, to provide emergency trauma care is equally a problem. In Kenya, the EMTs are not recognized by the government. Most of the EMTs are employed by private EMS providers (Naughton et al., 2014). Furthermore, there are few Emergency Medicine (EM) specialists in Kenya. Emergency Medicine (EM) was recently included as a medical practice specialty in Kenyan universities by the Clinical Officers Council (COC) and Kenya Medical Practitioners and Dentists Board (KMPDB). Graduates of EM courses are expected to help bridge the trauma and emergency skill gap. Currently, Emergency Departments (ED) in Kenya and other LMICs are mainly staffed by clinicians (Clinical Officer and Medical Officers) who lack adequate emergency care training, especially for critically injured trauma patients.

In Kenya, medical officers and anesthesiologists are responsible for the operations and management of trauma patients at the ED and in the intensive care units (Thompson, 2013). However, this is limited to well-resourced private facilities and a few tertiary hospitals, while in lower facilities, Emergency Departments (EDs) are mainly manned by medical doctors, clinicians, and resident medical students who have limited basic EM training. The situation could be worse in primary care facilities in tiers 1 and 2 of the healthcare system in Kenya, particularly those located in rural and remote areas manned by one or two clinical officers.

Most of the EDs in these health facilities are staffed with clinicians and nurses with about three-year medical college training with limited to no critical and emergency trauma care skills, such as resuscitation, intubations, and stabilization of critical trauma patients (Martin, 2011; Wachira et al., 2012).

There is a gross lack of general population awareness and response capability (community-based emergency response) on trauma incidents requiring the administration of first aid care. In Kenya, lay responders, the majority of whom lack first-aid or critical care skills, are the first to arrive at injury scenes such as RTIs, violence, falls, fire, and building collapse (Heidari et al., 2019; Oliver et al., 2017b, 2017a). For instance, in a Kenyan study, 70% of participants had witnessed one or more traumas involving RTIs, assaults, fire burns, falls, violence, and gunshots, yet the majority did nothing to assist due to a lack of basic first aid skills (Broccoli et al., 2015a).

Most of the staff administering prehospital care at the injury scene are often untrained and lack the knowledge to care for trauma patients (Obermeyer et al., 2015; Thompson, 2013). Police officers and community members (lay responders) constitute first responders in most instances but have no EMS training for recognition, stabilization, and evacuation (Broccoli et al., 2015a). There are no functional community-based emergency response systems in Kenya (Heidari et al., 2019; Nielsen et al., 2013). This exposes critically injured trauma patients to the care of poorly qualified health professionals and well-wishers.

1.2.5 Capacity of PEC in Kenya

Lately, prehospital emergency care has received increasing attention worldwide (WHO, 2016). The scoping study findings show that the design and implementation of a locally responsive prehospital EMS can mitigate about 45% of post-trauma mortality and about 36% of related disabilities in LMICs (Dewan et al., 2019; Koome et al., 2020; Obermeyer et al., 2015;

Tropeano et al., 2019; Wesson et al., 2014). In Kenya and other African countries, existing health systems have prioritized infectious disease burden over non-communicable disease burden such as TBIs. Over time, the burden from non-communicable diseases, including injury-related disability, has increased tremendously beyond the capacity of the health systems to adequately respond (Calvello et al., 2013b; Marsh et al., 2015; McCoy et al., 2013b).

Kenya is considered one of the ten LMICs that contribute to about 50% of the world's traffic accidents, primarily due to weak and poorly developed prehospital care systems to respond to traumatic incidents (World Health Organization, 2014, 2016). Designing horizontally integrated EMS at the prehospital care level can significantly address this unmet public health need, especially for trauma and injury burden (Calvello et al., 2013b; Martin, 2011). Kenya lacks standard prehospital care, including but not limited to EMS policy, legislation, EMS standards on communication, evacuation, training, and curricula (Martin, 2011; Thompson, 2013; Wachira et al., 2012). This has led to the emergence of fragmented and uncoordinated EMS with different EMS providers operating independently. The system is labeled as 'sporadic, fragmented, and parallel', resulting in missed opportunities for life-saving interventions (Balikuddembe et al., 2017). This has been precipitated by poor governance and leadership of the system (Broccoli et al., 2015a; Wesson et al., 2015) linked to the lack of prioritization and poor performance of the PEC systems (Mould-Millman et al., 2015; Reynolds et al., 2017).

Access to specialized and well-resourced trauma care facilities is also a key determinant of trauma outcomes (Sasser et al., 2005). There is a limited number of well-equipped and coordinated ambulance rescue services and EMT training targeted for out-of-hospital settings. The few public ambulances available are not deployed in the out-of-hospital settings but rather stationed at the facility for inter-facility transfers (Tansley et al., 2015; Zafar et al., 2014). During referrals, very few critically injured patients are accompanied by a trained nurse, which

depicts the existing staff shortage amid a lack of essential facilities and equipment to aid quality response and care (Okello and Gilson, 2015).

Private and faith-based facilities remain inaccessible due to limited coverage and the inability to afford the high service costs for most of the poor and vulnerable casualties (Martin, 2011). The majority of traffic crash victims are transported via private transport or non-ambulance vehicles (Broccoli et al., 2015a; Martin, 2011; Wachira et al., 2012). This is partly due to a lack of enough ambulances leading to long waits, which has negative implications for life-saving interventions. For instance, the average ambulance waiting time in Kenya is almost one hour, with the overall prehospital time exceeding the recommended 60 minutes or golden hour concept (Sultan et al., 2019).

In most counties, especially in rural and remote areas, the main means of transport available to lower-level facilities are motorcycles (Mulaki and Muchiria, 2019). The lack of well-equipped and staffed ambulances precipitates the traumatic burden further worsened by poor infrastructure, including impassable or poorly maintained road networks. However, there is no robust locally-generated scientific evidence to affirm the role of transport mode on traumatic mortality outcomes for TBI in the country.

In most cases, the first contact or transfer health facility after injury, usually public, lacks the basic facilities, equipment, and skills to provide basic trauma support care (Boschini et al., 2016). This leads to frequent referrals to often crowded tertiary hospitals, resulting in avoidable prehospital delays and worse outcomes due to the lack of time-sensitive life-saving interventions in the primary care facilities and en route to the hospital. At the prehospital care level, there is inconsistent adherence to patient referral and prioritization protocols, which leads to long queuing for critically injured patients, hence higher rates of avoidable mortality and disability (Thompson, 2013). The system lacks clear response guidelines, deployment of

trained providers, and referral coordination. According to Broccoli et al., there are also difficulties in communication due to the lack of central emergency phone lines and rescue coordination, leading to disjointed responses (Broccoli et al., 2015a).

With limited prioritization and government-led financing of PEC, the lack of health insurance cover for prehospital care is a persistent challenge hindering the strengthening of existing health systems in Kenya (Broccoli et al., 2015a; Mulaki and Muchiria, 2019). Pre-hospital care reimbursements for pre-hospital EMS care are unavailable to most populations, especially those in marginalized areas, including health insurance policyholders (Suryanto et al., 2017). Where available, insurance provider pre-authorization and reimbursement processes, such as the National Health Insurance Fund (NHIF), present major bottlenecks to use in the pre-hospital care settings, which widens the care access gap (Barasa et al., 2018a). Most of the poor and vulnerable patients don't have any form of health insurance. Approximately only 25% of Kenyans, mostly in the upper wealth class, have any form of health insurance, public, private, or community health insurance (Barasa et al., 2018a, 2018b). This means about 75% of Kenyans rely on out-of-pocket payment for their healthcare.

In most health insurance schemes, the benefits are either low or not inclusive of prehospital ambulance rescue services, hence exposing most of the patients (Kuzma et al., 2015b). This is a gap to strengthening and resourcing EMS at the prehospital care level. With the commitment to achieve universal health care goals through financial protection, Kenya may need to invest more in integrated prehospital care systems (Mulaki and Muchiria, 2019). This is underscored by finding that many trauma deaths occur in the out-of-hospital care settings than other levels of care due to weak prioritization and financing of PEC reforms. Increasing resources and development of this level of care are core to sustainable socioeconomic and health development of the nation.

1.2.6 Statement of Research Problem

Globally, PEC (Prehospital Emergency Care) is recognized as an integral intervention in mitigating high trauma burdens, including preventable mortality and disability (Suriyawongpaisal et al., 2014). However, as reported in the status of PEC in Kenya, resource-constrained countries, including Kenya, do not prioritize PEC as a high investment despite the high burden of avoidable TBI (Traumatic Brain Injury) cases. As a result, TBI remains a serious public health problem, contributing to increasing mortality and morbidity rates. The dysfunctionality of the PEC system has been attributed to the high burden of preventable TBI mortality, which is a persistent concern for human rights and economic development in Kenya. For instance, TBI burden accounts for 6% of global DALYs (Disability-Adjusted Life Years) (WHO, 2014), with Kenya and other LMICs (Low- and Middle-Income Countries) accounting for more than 80% of this burden.

In Kenya, inherent gaps in PEC functional capacity may be contributing to a significant proportion of this potentially avoidable public health burden. These PEC gaps include, but are not limited to, inadequate access to quality and timely life-saving critical care, inefficient pre-hospital transport, mishandling of critically ill patients, shortage of emergency care skills, and a lack of an enabling policy environment (Broccoli et al., 2015). For instance, a policy review conducted in Kenya revealed that the Kenyan PEC system is ineffective in providing life-saving critical care due to system-wide capacity weaknesses (Isaac et al., 2016). The review recommended policy reforms, staff training, improved evacuation management, and harmonization of service delivery as core improvement areas.

Over time, the lack of reliable local evidence to inform locally-effective PEC system design and trauma response practices has led to over-reliance on Western-based studies to inform policy and program practices. However, due to contextual differences such as access to advanced medical technologies, an enabling policy environment, and highly competent care

providers, this evidence may not adequately address the unique local challenges and opportunities in critical trauma care. For instance, the adoption of the "golden hour" practice in ambulance evacuation has been shown to improve prehospital TBI functional outcomes in high-income country settings (Curtis et al., 2016; Newgard et al., 2010; Pham et al., 2017). However, this practice may not be practical or effective in low-resource contexts such as Kenya, characterized by multiple systemic and structural weaknesses, including a lack of well-organized and resourced ambulance evacuation services at the PEC level.

Based on a review of available literature, there is no local empirical evidence to affirm the role of these PEC factors and practices in improving functional TBI outcomes at this level (Thompson, 2013). This lack of evidence has also contributed to limited investment or prioritization of PEC in establishing an integrated system. Availability of locally-adapted empirical evidence can be an effective advocacy tool for policy and service delivery reforms. For instance, while the Constitution of Kenya (CoK), 2010 guarantees access to quality emergency care, the enactment of relevant legislative and policy frameworks to actualize this right remains a major structural gap. This gap exists despite the increasing TBI burden attributable to weaknesses at the PEC phase. The country lacks solid empirical insight that can establish the linkage between an integrated PEC and improved trauma outcomes (Thompson, 2013). Relatively more investment has been channeled towards strengthening in-hospital care systems compared to the development of a functional and quality service delivery at the PEC level.

One feasible solution to this public health problem is to strengthen the generation of reliable local evidence to inform advocacy, as well as the development of locally relevant policy and programmatic actions to mitigate the escalating TBI burden. This constitutes an urgent need for policy research on the role of PEC factors, such as access to prehospital life-saving care and the type of referral system used, on post-trauma health outcomes, specifically mortality.

This study sought to generate this policy evidence and insights while determining critical care delivery gaps and areas of improvement at the PEC level. The findings present valuable insight into the role that an effective PEC system (PEC factors) can play in mitigating the TBI mortality burden through access to quality life-saving care in Kenya and other LMICs.

1.2.7 Rationale for the Study

There is limited local scientific evidence to guide the development of responsive prehospital care systems to address the high unmet traumatic injury needs, especially Traumatic Brain Injuries (TBIs). TBIs are one of the most common traumatic injuries, and the role of emergency prehospital care in these acute trauma conditions is among the least studied in Kenya, Africa, and other low- and middle-income countries (LMICs). Prehospital emergency care has received limited attention from the government in terms of policy, service delivery programs, and related budgetary allocations.

There is a policy and programmatic over-reliance on studies and evidence based in Western countries, which have different operational contexts compared to LMICs that face serious resource constraints. The investment portfolio for prehospital emergency care for acute traumatic conditions in high-income countries (HICs), such as financing, staffing, and infrastructural capacity, is significantly higher than in LMICs (Broccoli et al., 2015a). For instance, despite Sub-Saharan Africa accounting for about 80% of TBIs and other trauma burden, only a paltry 20% of related empirical studies are contributed by Africa.

The economic cost of TBIs, include mortality, morbidity, and high hospital bills, has a serious economic impact at the individual, household, and societal levels (Hadley K.H. Wesson et al., 2015). For instance, LMICs, mainly in Sub-Saharan Africa, lose approximately 4 billion United States dollars (US$) annually due to Road Traffic Injuries (RTIs), a major cause of TBIs. This is equivalent to 11% of their Gross Domestic Product (GDP) (WHO, 2016). In Kenya, the cost

of RTIs is estimated at 14 billion Kenya shillings per year (Matheka et al., 2015). Injuries account for 88.4 deaths per 100,000 population (Hadley K.H. Wesson et al., 2015). This study provides valuable empirical evidence on policy and programmatic investment priorities that will help avert this cost by increasing access to quality critical trauma care for all.

The findings also provide insight into the role and value-added of prehospital emergency care in improving population health outcomes for TBI patients in Kenya. In the context of increasing traumatic injuries, especially TBIs, which have become a top global and in-country cause of avoidable death and mortality, the evidence pinpoints critical policy and service delivery gaps that are critical in re-engineering TBI life-saving care response gaps within the healthcare system in Kenya. This evidence remains grossly lacking in the country to anchor data-driven advocacy and related decisions. This study also advances the aspirations of the partially implemented Kenyan Constitution provision on access to quality emergency care and the United Nations (UN) Strategic Development Goal (SDG) 3 aim of ensuring healthy lives and well-being for all.

1.3 Study Questions

The study was guided by the following research questions:

1. What are the patient-related characteristics that influence TBI mortality at the prehospital care (PEC) level?
2. What is the association between trauma patterns and TBI mortality at the PEC level?
3. What is the association between access to PEC and TBI mortality?
4. What is the association between the type of patient transfer pathway and TBI mortality at the PEC level?

1.5 Study Objectives

1.5.1 Main Objective

The main objective was to establish the association between prehospital emergency care (PEC) factors and Traumatic Brain Injury (TBI) mortality in Kiambu and Nairobi counties, Kenya.

1.5.2 Specific Objectives

The specific objectives of the study were:

1. To examine the influence of patient characteristics on TBI mortality at the PEC level;
2. To determine the association between trauma patterns and TBI mortality at the PEC level;
3. To determine the association between access to prehospital emergency care and TBI mortality;
4. To determine the association between the type of patient transfer pathways and TBI mortality at the PEC level.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section begins with a general overview of trauma burdens and patterns, including general trauma and traumatic brain injury (TBI). It is followed by empirical literature on EMS responders, prehospital care interventions, prehospital transport and referral pathways, a comprehensive review of key contextual health system factors such as policy, governance, leadership, and the role of patient demographics in mortality outcomes. A summary of the literature review was conducted to synthesize relevant scientific evidence and identify gaps, followed by sections on the statement of theoretical and conceptual frameworks underpinning the study and a summary of study gaps.

2.2 Trauma Burden and Patterns

2.2.1 General Trauma (All forms of Trauma)

Globally, injuries and related trauma remain a serious public health problem (Kong et al., 2017). Injuries are estimated to account for approximately 10% of the total annual global mortality. A study conducted in Australia showed that traumatic brain injury (TBI) is a major cause of disability and death among young individuals worldwide (Keijzers et al., 2015). An exploratory study in the UK reported that approximately 800,000 injury-related deaths occur globally each year, with a higher incidence among young adults aged below 45 years, particularly males and unmarried individuals (Thompson et al., 2017a). The World Health Organization (WHO) estimates that traumatic injuries are responsible for at least 6% of all years lived with disability worldwide, with low- and middle-income countries bearing the greatest burden, accounting for approximately 80% of injury-related deaths (WHO, 2014).

A secondary data review conducted in the UK reported negative outcomes associated with TBIs, including mortality, significant medical costs, long-term disabilities and complications, psychological distress, discomfort, and loss of productivity, among others (Thompson et al., 2017a). Despite the high burden and cost of trauma in low- and middle-income countries (LMICs), prehospital care systems in these countries are poorly developed compared to high-income countries. Furthermore, an econometric study conducted in Ghana concluded that LMICs lack solid empirical evidence to inform responses to local trauma burdens, needs, and priorities (Tansley et al., 2015). The main causes of traumatic injuries are road traffic injuries (RTIs), violence, and falls. Studies conducted in Indonesia and Mozambique have confirmed that RTIs pose a significant public health concern in LMICs (Suryanto et al., 2017; Taibo et al., 2016).

Globally, approximately 1.2 million RTIs occurred in 2012, with the most affected group being male individuals aged 15-29 years (Ladeira et al., 2017). The burden of RTIs and other traumatic injuries remains a growing concern in Kenya specifically. A review of the Kenyan Prehospital Emergency Care (PEC) system found that more than 75% of patient visits in the casualty department were due to traumatic cases, mainly from RTIs (Wesson et al., 2015). In particular, there were 2,919 fatalities from RTIs recorded in Kenya in 2017, which represented a slight reduction compared to the 2,965 fatalities reported in 2016.

In Ghana, most injury-related trauma was reported among pedestrians and unrestrained passengers (Tansley et al., 2015). Similarly, in Kenya, pedestrians accounted for the highest number of fatalities (1,060), followed by passengers (773) and motorists (715). Additionally, there were 3,943 serious injuries and 4,353 minor injuries reported (National Transport and Safety Authority (NTSA) Annual Report, 2018). Road traffic injuries are projected to increase by approximately 80% over the next decade due to an increase in motorization and low adherence to road traffic regulations (WHO, 2016). The burden is significantly higher in

developing countries, especially in the African continent, which is also ill-equipped to manage this burden, as in the case of Kenya. A study conducted in Nigeria revealed that the high burden of RTIs is compounded by the lack of well-developed and capacitated prehospital systems to adequately respond to local trauma needs (Adeloye, 2012).

In LMICs, trauma mortality rates at the prehospital care level remain high (Edem et al., 2019; Mahama et al., 2018). A review of secondary data in Nigeria found that approximately 30% of deaths from traffic-related trauma could be prevented with the availability of adequate prehospital medical care and evacuation (Adeloye, 2012). Prehospital delays and delays in receiving advanced critical care at the hospital level are the main contributors to preventable trauma mortality (Adeloye, 2012; Edem et al., 2019). Similarly, another study in Nigeria found that delay in seeking care was the main cause of preventable Early Inpatient Deaths (EIDs) (61%) as well as post-trauma mortalities (59%). The study reported that lack of timely access to care was an important risk factor for trauma mortality. Among deaths that could have been prevented, the most common causes were central nervous system (CNS) injury, hemorrhage, and airway obstruction (Adeloye, 2012; Edem et al., 2019). In addition, the study highlighted the absence of adequate resuscitation fluid (37%) and delayed prehospital care (37%) as significant gaps in care (Adeloye, 2012). These findings reflect a worsening public health concern in the context of poorly developed and capacitated prehospital systems to adequately respond to and meet local trauma needs.

Despite LMICs bearing the highest burden of traumatic injuries, countries such as Kenya and Nigeria have limited numbers of health and trauma specialists who can be deployed to provide prehospital trauma care without affecting in-hospital care delivery (Allgaier et al., 2017). This is further compounded by a lack of infrastructure, such as well-equipped Intensive Care Units (ICUs) with sufficient capacity to handle severe traumatic injuries, especially central nervous system (CNS) injuries. For instance, a study in Kenya showed that there are less than 100

functional ICUs in public hospitals, despite an increasing need for EMS and ICUs (Murthy et al., 2015). The situation is exacerbated by high levels of poverty among the general population, making specialized trauma care services unaffordable for the majority of individuals.

At the PEC level, different trauma patterns are reported (Mock et al., 1998; Okemwa, 2004). In the case of traumatic injuries, the main body regions affected are the musculoskeletal system (60%) and the head (52%). A meta-analysis study in LMICs found that wounds (65%) and fractures (26%) are the most common types of injuries sustained (Chalya et al., 2012). The study also revealed that patients with severe trauma (GCS≤9) and those with long bone fractures have a significantly longer hospital length of stay. A retrospective study conducted in Ghana showed that penetrating injuries, particularly gunshots, accounted for the majority (64.5%) of the trauma burden (Mahama et al., 2018).

A retrospective review of patient charts found that blunt trauma was commonly reported in motor vehicle collisions and falls (Strnad et al., 2015). An Ethiopian study found that the most common emergency scenes were homes (51.8%) and roadsides (37.1%) (Sultan et al., 2019). In Kenya and other African countries, the common injury mechanisms were traffic-related crashes, followed by falls and pedestrians. (Chalya et al., 2012; Eefect et al., 2016; Suryanto et al., 2017). A study in Tanzania found that motorcycles were highly responsible for a significant proportion of road traffic crashes, coinciding with an increase in motorcyclists in Africa (Chalya et al., 2012). In Ghana, 50% of trauma cases were related to traffic-related injuries, followed by falls (Suryanto et al., 2017).

Trauma-related costs have significant implications for the economy, individual productivity, and overall population health (Murthy et al., 2015). In the healthcare context, trauma-related injuries are associated with an increasing number of hospital admissions, emergency visits, medical bills, and mortalities (Murthy et al., 2015). Effective prehospital care systems can

prevent a significant proportion of this burden. For example, in Chesire, approximately 54% of prehospital trauma deaths occur among the injured who have a likelihood of survival (Oliver et al., 2017a). In Ghana, about 50% of prehospital mortality related to injuries were preventable through responsive prehospital care (Mould-Millman et al., 2015). Without proper prehospital care EMS interventions, an estimated 80% of trauma-related deaths and disabilities in LMICs are predicted to continue dominating the prehospital care level (Henry and Reingold, 2012). This has been attributed to the lack of well-developed prehospital care systems (Kong et al., 2017; Taibo et al., 2016).

No known study was found to examine the effect of injury day, type of injury, and injury mechanisms on mortality among TBI patients in out-of-hospital settings. Existing studies mainly focused on the description of trauma patterns. This reflects knowledge gaps that the study sought to address in order to inform trauma-specific prevention and response measures. Characterizing trauma patterns is an important component of any locally-responsive trauma care and response system. Understanding and mitigating the presentation of trauma and identifying potential risks for mortality are crucial in developing preventive, curative, and rehabilitative strategies for trauma.

In Kenya, like other LMICs, key primary preventive measures for trauma management include adherence to road safety measures and laws, such as using motorcycle helmets and observing road traffic regulations. However, there is consensus that these public health and injury prevention measures have failed to produce the desired reductions in mortality and disability (Edem et al., 2019). These low-resource environments may require distinct, unique, and context-specific systems to respond to specific trauma needs and priorities based on injury characteristics and patterns. There are limited context-specific studies to inform policy practitioners in aligning trauma response priorities with local trauma needs and priorities. In line with these gaps, the study examined the role of trauma mechanism, injury type, and day

on mortality for patients in out-of-hospital settings. The evidence is valuable in supporting the improvement of locally-adapted prehospital EMS responses aimed at mitigating the high trauma burden in Kenya and other low-resource countries.

2.2.2 Traumatic Brain Injury (TBI)

Globally, traumatic brain injury (TBI) remains a serious public health problem and is the leading cause of injury-associated disability and deaths (WHO, 2010). The burden of trauma has significantly increased in recent years, with over 69 million people suffering from TBI annually, mainly due to road traffic injuries (RTIs), violence, and falls (Taibo et al., 2016). The most affected group is males aged 15-29 years (WHO, 2016). In the European Union (EU), over 1.5 million people are admitted to hospitals for TBIs, but there are variations in admission rates among countries. Austria and Germany report eight times more admissions compared to Portugal and Spain. Additionally, EU hospital admission rates, adjusted for population, are three times higher compared to the United States (Tropeano et al., 2019). Annually, an estimated 1.4 million TBI cases are reported, resulting in approximately 50,000 deaths, 230,000 admissions, and 1.1 million treated and discharged cases, with the most affected age group being below 40 years (Tropeano et al., 2019).

Low- and middle-income countries (LMICs) bear nearly three times the global burden of TBIs, despite being poorly equipped to provide quality trauma care, especially at the prehospital care level (Dewan et al., 2019). Africa accounts for about 80% of this global burden, and most of the TBIs in LMICs are potentially preventable through the implementation of quality prehospital care systems. The high proportion of potentially preventable TBI deaths is a concern in LMICs worldwide (Yeboah et al., 2014). In Kenya specifically, the public health burden of traumatic brain injuries is a growing. concern. For instance, a South African study estimated that injury-related deaths, a major source of TBIs, account for approximately 800,000

deaths annually (Edem et al., 2019). According to the World Health Organization (WHO), road traffic injuries are expected to increase by about 80% in the next decade due to motorization, low adherence to road traffic regulations, and the lack of effective Emergency Medical Services (EMS) at the prehospital care level (WHO, 2016). There are increasing concerns that prehospital care EMS systems are ineffective and incapable of adequately mitigating the increasing number of TBIs requiring critical care interventions.

Traumatic brain injuries have social and economic impacts that extend from the victims to the affected families and the community as a whole. The economic cost of TBIs, including mortality, morbidity, and high hospital bills, has a significant impact on individuals, households, and society (Wesson et al., 2015). For example, LMICs, mainly in Sub-Saharan Africa, lose approximately 4 billion US dollars annually due to road traffic injuries, a major cause of TBIs. This is equivalent to 11% of their Gross Domestic Product (GDP) (WHO, 2016). In Kenya, the cost of road traffic injuries is estimated at 14 billion Kenyan shillings per year (Matheka et al., 2015). Injuries account for 88.4 deaths per 100,000 population (Wesson et al., 2015). According to a retrospective cross-sectional study conducted in South Africa, nearly half (48%) of TBI-related mortality occurs among individuals under 40 years of age, who contribute significantly to the country's economic productivity (Allgaier et al., 2017). This confirms that LMICs bear a disproportionately high burden of TBIs and other injuries.

A Kenyan study on patterns of traumatic injuries attributed the majority of the trauma mortality and morbidity burden to poor access to quality emergency care and delays in receiving definitive care at specialized trauma facilities (Gathecha et al., 2017). In developed countries such as America and Europe, approximately half of preventable post-injury deaths have been attributed to systemic weaknesses at the prehospital care level (Oliver et al., 2017a). The proportion and impact of these weaknesses are estimated to be three times higher in LMICs

compared to developed countries (Dewan et al., 2019). In Africa, preventable mortality, including TBIs, is reportedly higher at the hospital care level than at the prehospital care level (Adeloye, 2012; Edem et al., 2019; Mahama et al., 2018; Usselman, 2017). This is due to the lack of quality prehospital care and EMS systems.

This study describes Kenya's EMS as fragmented and poorly coordinated. Weaknesses in the system have been linked to inadequate resources, staff, leadership, lack of training standards and frameworks for TBI specialists, lack of an effective communication system, and ineffective EMS response systems. In Kenya and other low resource countries, there is lack of evidence to support locally-adaptive life-saving interventions to reduce preventable TBI mortality (Wesson et al., 2015). A literature review conducted in low- and middle-income countries found minimal investment in prehospital care, which weakens the efficiency and effectiveness of EMS responses (Nielsen et al., 2013).

An ideal trauma response and emergency care system for TBIs, should be fully equipped to provide quality and timely critical coordinated life-saving interventions. These interventions include stabilization of emergency incident victims, transportation or evacuation, coordinated referral pathways, accurate and relevant documentation, and the involvement of qualified emergency care providers at the prehospital care level. A Nigerian study found that proper coordination and implementation of these critical interventions can significantly improve the survival of victims of emergency incidents, including TBI (Adeloye, 2012).

In high-income nations, a systematic literature review found that quality prehospital care improves trauma-related mortality in the prehospital chain of survival for cardiac arrest, acute stroke, and trauma care (Van et al., 2016). In Kenya and other low-resource countries, the role of prehospital care responses in TBI is documented in the literature (Mould-Millman et al., 2013; Obermeyer et al., 2015). However, there is a need for evidence to inform the design of

resilient prehospital care systems that can respond to the specific local needs related to TBI, and this remains a study gap and priority in Kenya.

2.3 Access to Prehospital Emergency Care (PEC)

2.3.1 Development of Prehospital Care

Over the years, new and advanced medical interventions have been developed and proposed for the management of traumatic injuries. In many developed countries with mature Prehospital Emergency Care (PEC) systems, many of the interventions reserved for advanced in-hospital care are now provided in the prehospital phase of trauma care (Rehn et al., 2011).

At injury scenes, the EMS team in prehospital care is expected to stabilize patients, which includes activities such as correcting hypoxia or hypotension and controlling the airway for unconscious patients. To improve outcomes, prehospital trauma care and interventions have also continued to evolve with new guidelines and interventions, resulting in positive health outcomes among patients with severe injuries. The goal of these trauma management guidelines and medical interventions in the prehospital settings has been to prevent secondary traumatic injuries such as hypoxia or hypotension through early interventions, thereby reducing the incidence and impact of related complications, disabilities, and deaths (Ebben et al., 2013) (Koller et al., 2016). However, their efficacy and effectiveness in prehospital settings remain controversial due to a lack of sufficient studies to validate the outcomes.

2.3.2 Role of pre-hospital life-saving interventions

A systematic review found that the provision of effective and timely interventions after trauma can reverse and prevent a large proportion of post-trauma mortality (Ebben et al., 2013). In an Australian study using mixed methods in a developed country, it was concluded that the first three hours post-injury present a critical time period for successful medical care intervention

(Curtis et al., 2016). In other studies conducted in developed countries, the first hour post-injury, specifically 60 minutes, presents a critical time period for successful life-saving or care intervention (Curtis et al., 2016; Lerner and Moscati, 2001; Pham et al., 2017). However, similar studies in LMICs on the role of "60 min" evacuation practice are missing, hence a gap in validating the evidence in the context of low resource settings.

There are three common pre-hospital care interventions provided at the PEC level: (i) Basic Life Support (BLS), (ii) Advanced Life Support (ALS), and (iii) Lay responder, also called "No prehospital care" in this study. Basic Life Support (BLS) services involve providing adequate ventilation, oxygenation, and securing of the airway (Thompson et al., 2017b). It incorporates interventions aimed at stabilizing a patient until they can receive better and full medical care in hospitals. Trained medical individuals, such as paramedics, emergency medical technicians, and qualified trained bystanders, can provide this form of intervention.

Basic Life Support can include bleeding control, providing assisted ventilation and fracture immobilization as needed, spine stabilization, oxygen administration, and airway adjuncts. For instance, pre-hospital deaths can occur due to uncontrolled hemorrhage, respiratory failure, and/or airway compromise. As a result, a retrospective study in Mozambique recommended the provision of BLS interventions to trauma patients in the pre-hospital care setup (Taibo et al., 2016). In Kenya, some patients accessing prehospital care receive BLS, while others receive no interventions due to a lack of equipped ambulances, supplies, and trained EMS providers (Gathecha et al., 2017). However, the implications of this access on TBI outcomes have not been examined.

In developed countries, ALS has been integrated at the PEC level using well-equipped, resourced, and centrally coordinated ALS ambulances with trained EMS staff. Advanced Life Support (ALS) is defined as a set of skills and life-saving protocols that extend BLS to further

provide adequate breathing (ventilation), an open airway, and enable circulation. These interventions include rapid sequence induction, endotracheal intubation (ETI), cardiac defibrillation, cardiac monitoring, transcutaneous pacing, chest tube insertion, intravenous fluids (IVs), and anesthesia induction, among others. However, in Kenya and many other LMICs, ALS is not provided due to weaknesses in the PEC system capacity, such as ambulances, staff, and coordination.

Providing quality ALS can be resource-intensive for countries like Kenya. For instance, to ensure patient safety, a comparative cohort study conducted in developed countries concluded that the use of ALS at the PEC level requires extensive EMS staff training, sophisticated ambulance equipment and facilities, regular clinical practice, retraining, and many years of on-the-job experience under a qualified practitioner (Lyon et al., 2015). It equally requires a conducive and enabling environment supported by adequate equipment and facilities for the procedure (Kirves et al., 2010). In Kenya, this level of care is mainly provided by well-trained physicians with many years of experience and training at the emergency department of selected secondary and tertiary hospitals.

Scientific evidence on the efficacy of ALS in improving mortality outcomes at the PEC level remains mixed (Rognås et al., 2014; Sanghavi et al., 2015). In developed countries, ALS provided by qualified providers in EMS is reported to increase the survival rate of patients and life years gained (Van et al., 2016). Other similar studies reported insignificant differences in trauma outcomes for ALS (Fevang et al., 2017; Rossaint et al., 2016; Sollid et al., 2013; Thompson et al., 2017b). In other studies, ALS is perceived to cause unnecessary delay at the injury scene attributed to delays in definitive care. Advanced Life-Support (ALS) requires extended time on the scene to conduct complex invasive procedures such as endotracheal intubation, which are time-consuming (Sanghavi et al., 2015; Sollid et al., 2010). However,

reviews acknowledge the global lack of sufficient evidence and studies on the efficacy, effectiveness, and value of ALS in improving health outcomes, especially in Kenya and other LMICs (Sanghavi et al., 2015). Due to resource limitations and a lack of robust local evidence to support its efficacy, the WHO recommends that developing countries like Kenya to prioritize implementing BLS instead of ALS (Thompson et al., 2017b).

In Kenya and other low-resource countries, the value of the different life-saving interventions provided at the PEC level has not been extensively studied to inform cost-effective EMS interventions. Furthermore, due to technological advancement, the scope and nature of life-saving interventions available at PEC, including automated life-saving equipment, continue to evolve (Ebben et al., 2013). This requires more empirical studies to assess the efficacy and effectiveness of the new innovative approaches in prehospital care practices, both locally and globally.

In Kenya, the extent of use, efficacy, and effectiveness of various life-saving interventions on TBI outcomes at the PEC level is not well researched, hence the lack of solid evidence to inform policy adoption and best practices (Koller et al., 2016). This empirical evidence is fundamental in policy and programmatic advocacy of cost-effective interventions that confer adequate mortality benefits. This presents a scientific gap requiring additional similar studies at the PEC level.

2.3.3 EMS Providers and Trauma Mortality

The burden of TBIs is highest in LMICs compared to HICs (Adeloye, 2012; Obermeyer et al., 2015), attributable to a lack of quality prehospital emergency care (PEC) (Blom et al., 2014). Quality PEC requires trained EMS providers who are able to provide appropriate life-saving interventions at the injury scene, during transportation to the hospital, and in the emergency department of health facilities while awaiting referral to advanced facilities or admission for

definitive care. According to a Delphi study conducted in Uganda, which included TBI patients, gaps in first care skills force many trauma patients to rely on the "good Samaritan approach" to receive rescue assistance, including transport to a nearby hospital for advanced care (Balikuddembe et al., 2017).

In developing countries like Kenya, the role of first responders to traumatic injuries has been left to laypersons at the scene of the injury who lack the relevant skills and capacity (Peltokorpi et al., 2011). Ideally, in developed PEC systems, trained EMS teams in well-equipped ambulances should be the first care providers to arrive, assess the patient, and perform interventions at the scene of the injury (Falk et al., 2015; Jayaraman et al., 2009). The EMS teams are expected to have the necessary education, qualifications, skills, and experience to successfully perform time-sensitive life-saving interventions in out-of-hospital settings.

In developed countries, the provision of PEC by trained or skilled EMS teams has been attributed to a reduction in all forms of trauma mortality, including TBI (Van et al., 2016), but other studies have reported insignificant differences in mortality outcomes (Heidari et al., 2019; Jayaraman et al., 2009). However, in resource-deprived contexts like Kenya, there is no enabling infrastructure and policy framework to support rapid PEC by trained EMS providers (Broccoli et al., 2015b). For instance, due to a funding gap, there are no supportive EMS call centers with sufficient ambulances and skilled EMS staff deployed in out-of-hospital rescue settings to provide rapid rescue services (Broccoli et al., 2015b; Falk et al., 2015; Jayaraman et al., 2009; Peltokorpi et al., 2011).

In LMICs, EMS teams and paramedics lack the relevant competencies, which affect the efficacy of interventions and the quality of decisions made (Carpinter and Platts-Mills, 2014). The role of provider quality, skills, and competence on TBI mortality outcomes needs to be clarified, and evidence should be considered in developing effective training and capacity-

building opportunities for the staff. For example, during patient triaging, optimal decisions are needed to avoid over- triaging, which leads to unnecessary crowding of emergency departments, and to avoid under-triaging, which increases the risks of negative effects on patient prognosis caused by delayed care (Ghorbani et al., 2016; Lourens et al., 2019; McCoy et al., 2013).

Kenya and other LMICs lack the necessary capacity for effective and efficient triaging and management of casualties in out-of-hospital settings. A retrospective analysis of TBI patient data in Finland reported inadequate training resulting in unnecessary referrals, wrong referrals, and missed diagnoses (Raj et al., 2013). Some studies point to a positive link between paramedic education, skills, and competence at the scene of injury and ambulance transport and treatment outcomes (Carpinter and Platts-Mills, 2014; Sanghavi et al., 2015; Yeguiayan et al., 2011). In Kenya and other countries with weak PEC systems, studies on the association between the type of EMS providers and the efficacy of PEC outcomes, such as TBI mortality, are recommended to address gaps in published evidence. This insight will strengthen optimal decisions and care outcomes in the provision of PEC.

Unlike developed countries, there are very few, if any, trained lay responders, able to provide skilled first-aid care at injury scenes in Kenya. Untrained lay responders including bystanders, relatives, friends, and good Samaritans, at the scene of accidents lack the necessary skills to provide critical life-saving care to TBI patients. With no mechanism and supportive infrastructure to request skilled EMS rescue services, lay responders provide time-sensitive rescue and transport to hospitals (Heidari et al., 2019). Untrained lay responders have been linked to avoidable mortality risks due to mishandling of critical patients and delays in time-sensitive life-saving interventions, such as bleeding control when the distance to the transfer hospital is long and an appropriate transport vehicle is not available.

In other instances, trained lay responders have been shown to have the potential to contribute to improved PEC outcomes. Trained lay responder care has been associated with higher survival benefits due to reduced prehospital delays awaiting ambulances with skilled EMS staff (Heidari et al., 2019; Jayaraman et al., 2009; Möller et al., 2018). For example, studies conducted in Mexico and Uganda have reported training community members, including police, 'matatu' operators, and other volunteers, as a potentially effective model for improving all forms of emergency prehospital trauma care (Keijzers et al., 2014, 2015; Taibo et al., 2016). In Ghana, a prehospital trauma training course was reported to improve ambulance dispatch site management and patient handling by lay responders. Furthermore, in Uganda, patient management and crash scene management improved after the provision of first aid training to commercial drivers (Taibo et al., 2016).

The relevance of the knowledge generated in these studies is yet to be validated in Kenya and other contexts. Further studies on the role of Community-Based emergency response teams (CBER), in which lay responders or community members are trained to provide first-aid trauma care, are required. The use of the CBER model can present valuable opportunities to effectively address avoidable TBI mortality while tapping into the local resource skills of community members. This evidence may present localized and innovative opportunities in crafting local solutions to the high TBI burden in Kenya and other LMICs.

2.3.4 Prehospital Transport Mode

Trauma and related injuries are linked to an increasing number of hospital admissions and emergency visits, disabilities, significant medical expenses and fatalities. A substantial proportion of this public health burden can be averted by providing quality PEC using equipped, resourced, and coordinated EMS rescue services, such as ambulance rescues (Wesson et al., 2015). In the United States (US), a study by Sanghavi et al. found that efficient

and prompt evacuation of trauma patients provided a substantial mortality advantage to severely injured patients (Sanghavi et al., 2015). In the US, there are effective communication and call dispatch coordination centers linked to well-equipped and resourced ambulances with trained EMS teams. However, in Kenya and other LMICs, this evidence may not apply due to serious ambulance rescue gaps, such as a lack of ambulance command centers and equipped ambulances, among other challenges (Mould-Millman et al., 2015). This highlights gaps in local scientific evidence in the country and over-reliance on global studies that have contrasting contexts with LMICs.

Globally, efficient and prompt transport of TBI patients from injury scenes to a trauma care center is considered a fundamental principle in emergency rescue (Curtis et al., 2016; Newgard et al., 2010; Pham et al., 2017). However, due to capacity gaps, this principle is only partially adhered to in most countries. For instance, similar to Kenya, in Finland, a developed country, more than half of all trauma patients were transported in personal vehicles without proper handling capacity (Raj et al., 2013). In Kenya, a number of patients are initially transported to a primary hospital without the basic capacity to handle these trauma patients. The capacity is even almost non-existent for TBI cases, which require advanced diagnostic equipment, facilities, and specialists such as neurosurgeons.

In France, transporting severe trauma patients to primary health facilities without the requisite trauma capacity has been associated with a 50% higher risk of death (Bouzat et al., 2015). To avoid unnecessary delays and increase the survival rate, a Ghanaian study recommended direct ambulance transport of patients with proper care from the scene of injury to a specialized trauma center (Mould-Millman et al., 2015). In Kenya, TBI patients are transported by personal vehicles without no life-saving support equipment and facilities, which means they lack access to PEC (Möller et al., 2018).

Patient transfer to primary health facilities without TBI handling capacity may lead to longer total prehospital time due to delays in definitive care. The cost of delays in such critical conditions is too expensive to ignore amid increasing health rights activism and patient rights awareness (Sollid et al., 2013). Avoidable mortality can result in legal liabilities, loss of revenue through litigations, court fines, as well as damage to corporate brands. In Kenya, no equivalent studies on the association between total prehospital transport time and TBI mortality, including all forms of trauma mortality, have been found in the Kenyan context.

Kenya does not have coordinated PEC transport, including ambulance EMS rescue. This has left the provision of pre-hospital care to private EMS providers whose systems, although more efficient, are inaccessible due to cost and limited population coverage (Suriyawongpaisal et al., 2014; WHO, 2013). These private EMS providers include the Red Cross Society of Kenya, St. Johns Ambulance, and the African Medical and Research Foundation (AMREF) Kenya. Awareness of emergency contacts and services is also low (Wesson et al., 2015). As a result, access to EM services, both public and private, is limited.

Due to ambulance rescue capacity gaps, PEC transport is primarily done through non-ambulance means such as public vehicles, taxis, individuals walking -in, and private cars. The few ill-equipped public ambulances, known to have inadequate medical supplies, lack diagnostic equipment, and skilled EMS staff, are stationed in health facilities with limited dispatch to injury sites. Existing evidence shows mixed findings on the value of ambulance transport in different LMIC settings. A South African study found no significant association between all forms of trauma mortality and the transport mode used (Möller et al., 2018), but a similar Ghanaian study by Mahama et al. reported a significant association between the use of ambulance transport and a reduction in all forms of trauma mortality (Mahama et al., 2018). In the Kenyan context, considering the operational dynamics in which TBI patients are rescued,

the value-add of transport mode on TBI mortality outcomes may be insignificant. However, studies to support or refute this hypothesis are lacking (Suriyawongpaisal et al., 2014; WHO, 2016).

PEC Transport mode evidence documented in this review relates to all forms of trauma mortality rather than TBI mortality only used in this study, hence not fully comparable in this study. Further, this study examines ambulance transport as part of broader PEC which includes trained EMS and provision of life-saving interventions. The findings of this study will provide valuable insight not present in other past studies. Transport mode is a core component of effective EMS at the PEC level. Establishing the transport-mode adjusted mortality-benefits attributable to provision of PEC is fundamental in defining a complementary EMS for TBI responses at the PEC level.

In summary, the role of EMS responders/providers and the mode of prehospital transport in TBI mortality outcomes in Kenya and other LMICs is not well understood due to limited local evidence. Existing studies from other contexts have shown mixed findings, and the effectiveness of EMS providers and the impact of transport modes on TBI mortality outcomes in LMICs need to be investigated further to inform policy and practice.

2.4 Prehospital Referral Pathways and Trauma Care Hospitals

2.4.1 Type of Patient Referral Pathway

Traumatic injuries are a global public health problem, primarily concentrated in African countries (Obermeyer et al., 2015; Samanamalee et al., 2018). However, Africa and other LMICs (Low-and Middle-Income Countries) lag behind in terms of the availability, quality, and capacity of patient transfer and referral systems. The existing EMS (Emergency Medical Services) care systems lack basic infrastructure, experts, and facilities to support effective and safe patient transfer and referral for advanced critical care management (Kuzma et al., 2015a).

In this regard, the patient referral pathway (direct or indirect) and the choice of trauma care facility (private or public) may play a fundamental role in determining TBI (Traumatic Brain Injury) mortality. This study examined two types of patient transfer pathways; direct transfer, which involves transferring the patient from the injury scene to a tertiary facility, and indirect transfer, which involves transferring the patient from the injury site to a tertiary facility through primary health facilities.

In the context of weak pre-hospital care settings, global evidence emphasizes the concept of the "golden hour" in transferring patients from the injury scene to a trauma care hospital, although supporting evidence in the literature regarding its benefits is mixed (Curtis et al., 2016; Lerner and Moscati, 2001; Newgard et al., 2010; Pham et al., 2017). The available evidence suggests initiating life-saving interventions within the first hour of injury, also known as "the golden hour."

A Ugandan study revealed that most trauma mortality is due to delays in time-sensitive care patient transfer and referral when responding to acute conditions (Balikuddembe, et al., 2017). In low-resource environments like Kenya, TBI patients rescued by lay responders are transferred to the nearest primary hospital using non-ambulance transport (Balikuddembe et al., 2017; Boschini et al., 2016; Mehmood et al., 2018). For lay responders without ambulance transport, transfer pathway decisions are mainly based on the distance to the nearest trauma care facility without considering the hospital's capacity to provide required critical care (Kim et al., 2017).

The relationship between patient referral pathways and TBI mortality is mixed in the literature, and thus inconclusive. A retrospective study conducted in sub-Saharan Africa reported that direct transfer of trauma patients from the injury scene to the trauma hospital potentially confers a survival advantage by reducing the time spent in referrals from peripheral hospitals

(Boschini et al., 2016). Similarly, a systematic review study conducted in Newcastle, a developed country, recommended access to professional pre-hospital care within 5 minutes of trauma and within eight minutes for advanced and specialized trauma care in a tertiary trauma facility or center (Williams et al., 2013).

While the reviewed evidence supports the value of the golden hour in trauma distress and referral responses, existing studies in LMICs seem to contradict these findings, and there is a lack of strong empirical evidence to validate the findings in Kenya and similar contexts (Balikuddembe et al., 2017; Möller et al., 2018). Consequently, the benefits of various patient transfer pathways in reducing all forms of trauma mortality remain disputable, and there is a research gap, particularly regarding TBI cases.

2.4.2 Role of Trauma Care hospital

The literature review did not find any studies assessing the difference in TBI outcomes based on the type of tertiary hospital to which a patient is transferred or referred. In this study, mortality was defined using a one-month period (30 days) from the day of injury. The quality of care in tertiary hospitals may significantly vary between private and public hospitals. Adjusting for the type of hospital in mortality outcomes, whether private or public, which serves as a proxy indicator of quality of care, is recommended.

Differences in health outcomes based on the type of health facilities have only been explored in diverse in-hospital surgical outcomes, including but not limited to breast cancer, trauma, appendicitis, and colorectal cancer, among others, but not extended to the PEC (Prehospital Emergency Care) level (Gartstein et al., 2020). According to a Colombian study that applied a multivariate logistic regression model, health outcomes between private and public hospitals are similar but differ in LMICs. This affirms the capacity weaknesses observed in public hospitals compared to private hospitals in resource-constrained countries like Kenya. The

study conducted in Colombia among in-hospital patients found higher mortality risks in public hospitals compared to private hospitals (Gartstein. et al., 2020). Although the study was not linked to the PEC level, it indicates that access to well-equipped, staffed, and resourced trauma hospitals may provide a potential mortality advantage attributable to quality definitive trauma care. However, the findings may not be generalized to Kenyan settings, a developing country.

In Kenya and other LMICs like Colombia, private hospitals have less crowding but more investment in definitive care, including higher diagnostic equipment, improved technologies, advanced facilities such as theaters with new technical applications, motivated specialists and nursing teams, and robust staff performance monitoring structures compared to public hospitals. Public hospitals experience capacity limitations, in terms of infrastructure and staff accountability systems, which can adversely affect the quality of life-saving interventions at the emergency department and the provision of definitive care upon admission (Brown et al., 2016; Nielsen et al., 2013).

The quality of facilities may substantially adjust PEC-related mortality risks as part of the continuum of life-saving care. For instance, quality medical and nursing care in hospital settings has been associated with lower risks of all forms of mortality (Georgiou and Lockey, 2010). Gaining insight into the adjusted mortality risks associated with the type of trauma care hospital a patient from the PEC level is admitted to is essential in defining and advocating for the linkage between the PEC system and in-hospital care capacity for TBI. This study aimed to address this evidence gap by examining differences in adjusted TBI outcomes between private and public tertiary (trauma care) hospitals.

2.5 Contextual Factors in the PEC System

As part of a holistic system approach, this study incorporated a review of the role of contextual factors in the PEC system and their implications for TBI mortality, namely the policy framework and financing of the PEC in Kenya.

2.5.1 PEC System Policy and Governance Framework

Healthcare services are provided within a policy and legislative framework that provides the relevant context and requirements for quality care delivery. In Kenya, there is no comprehensive legislative framework regulating the PEC system. The existing frameworks – Kenya Health Sector Referral Strategy and Guidelines 2014, The Kenya EMS Strategy 2020-2024, The Kenya Health Sectors Strategic Plan 2018-2023 – are not PEC-specific (Balikuddembe et al., 2017). The PEC system is a broad interdisciplinary system requiring a dedicated policy and legislative framework addressing its diverse components, including but not limited to standards, staffing, infrastructure, and communication. The governance structure is currently fragmented and ineffective due to policy gaps (MoH, 2013).

Despite the Constitution of Kenya, 2010, guaranteeing access to health care and, in particular, access to timely and quality emergency care as a right, there is no equivalent PEC policy or legislation to support its implementation, such as funding of free care provided, relevant institutions with mandates to operationalize the constitutional provision, among others. In the absence of relevant EMS policy and institutional arrangements, there are no functional lead government agencies ensuring the setting and enforcing of EMS standards on other critical aspects such as staffing and training, communication and equipment, coordination, and regulation of pre-hospital care evacuations (Cornwell et al., 2000; Hsia et al., 2010a). These policy and legislative weaknesses may be the weak link contributing to the avoidable TBI mortality burden in the country. This reflects a state government with biased prioritization –

funding, infrastructural investment, staffing, and facility development – of communicable health burden at the expense of functional PEC to address the high trauma burden. In these settings, TBI contributes to more than half of the mortality burden (Taibo et al., 2016).

2.5.2 Financing of PEC System

EMS financing is a fundamental component of a well-equipped EMS evacuation system and access to quality services (Calvello et al., 2013a; Campbell et al., 2015; WHO, 2010). Cost is a significant determinant of access as well as the quality of care received. Poor financing structures, especially prehospital care, are a key cause of increasing health burden and risk to the poor, especially preventable deaths, higher medical bills, and long-term disability. A Kenyan qualitative study by Broccoli et al. identified budgetary and financing constraints as a key barrier to a quality pre-hospital transport system (Broccoli et al., 2015b). In this study, respondents expressed high dissatisfaction with poorly funded and managed pre-hospital and EMS systems in Kenya.

Inefficiencies in transport, such as avoidable referral delays, have been blamed on the lack of money to pay for ambulances, resulting in delays and an even higher rate of pre-hospital deaths (Wesson et al., 2015). The lack of effective ambulance transport from injury scenes has been noted to potentially increase the risk of all forms of mortality (McCoy et al., 2013a; Williams et al., 2013). For instance, patients with expensive and comprehensive health insurance have been reported to have higher chances of receiving air transport, and efficient ground evacuation. The disparity is high for the poor who cannot afford the expensive insurance cover (Campos Andrade et al., 2013; Gruen et al., 2012).

Identifying responsive, affordable, innovative, and inclusive financing mechanisms for pre-hospital trauma systems remains a high priority for governments in the race towards making access to emergency care a constitutional right accessible to all. Adequate PEC financing can

aid in the acquisition of priority diagnostic equipment, the development of trauma and ambulance call centers, ambulance rescue supplies, public awareness campaigns, training and deploying trained EMS providers – including lay responders – and the acquisition of well-equipped and resourced ambulances (Calvello et al., 2013a; WHO, 2010). The funding can also be used to finance affordable social insurance schemes for the most vulnerable.

In Kenya, the National Health Insurance Fund (NHIF) benefits package has been expanded to include the provision of pre-hospital rescue services (NHIF, 2017). In other models, some county governments have partnered with private EMS providers such as E-plus from the Red Cross Society to provide contracted services to county residents. The feasibility, relevance, and cost-effectiveness of these financing reforms have yet to be examined, although the model has not been sustainable in many of the counties. The service contract has been terminated due to funding gaps. The role of innovative financing mechanisms for TBI and related outcomes remains scarce across the world.

The review found inconclusive scientific evidence to demonstrate the value and effect of contextual PEC system factors like affordability, policy, and institutional leadership framework on TBI mortality, including all forms of mortality. These scientific gaps are amplified by a lack of reliable and comprehensive data – such as financing trends – and data capture systems for the PEC system to be used for these empirical studies. The study used qualitative approaches such as interviews and desk reviews to gather and draw insight into the role of these contextual factors on TBI mortality. Further empirical studies on the role of contextual systemic factors such as policy, leadership, and institutional structures in LMICs to inform actionable policy are indicated.

2.6 Role of Patient Demographics and Vital Characteristics on Trauma Mortality

A meta-analysis study in LMICs found patient characteristics to play a critical role in the provision of pre-hospital care (Chalya et al., 2012; Thompson et al., 2017b; Williams et al., 2016). In prioritizing interventions and care, individual casualty characteristics form critical components of patient assessments, triaging, and determining optimal interventions or care responses. These individual risk factors can provide useful insight into patient status even with limited invasive procedures and inform response and life-saving decisions. Due to the lack of well-functioning pre-hospital systems, most casualty assessments are done in hospitals, contrary to the expectation of an effective EMS evacuation system.

In countries with weak or non-existent prehospital emergency care systems, a Delphi Ugandan study found proper patient assessment missing at the scene of injury due to either a lack of skilled staff at the scene of injury, lack of appropriate equipment and facilities, and weak pre-hospital response coordination (Balikuddembe et al., 2017). This means critical data for prioritizing care and assessing the performance of the system is lost. This information and data can be a useful tool in informing the development of patient-centered care for optimal outcomes.

Many studies in LMICs examine the role of patient characteristics on in-hospital outcomes (Bala et al., 2013; Jokela et al., 2015). This limits the availability of evidence on pre-hospital trauma care and post-trauma outcomes in out-of-hospital settings. In addressing this study gap, the study collated and analyzed key patient vital statistics reflecting patient status in out-of-hospital settings.

The influence of patient characteristics such as age, gender, comorbidity, hypoxemia, and trauma severity is not consistent across studies conducted globally and in other LMICs. Review evidence from diverse settings shows young males aged 20-40 years account for the highest

proportion of trauma victims or incidence, mainly from Road Traffic Accidents [RTAs] (Adeloye, 2012; Balikuddembe et al., 2017; Boschini et al., 2016; Chalya et al., 2012; Möller et al., 2018; Steenkamp et al., 2017). Students or learners were the most injured (Chalya et al., 2012).

In the literature, older age has been shown to increases the risk of trauma mortality due to the presence of age-related comorbidities (Chalya et al., 2012; Roudsari et al., 2007; Thompson et al., 2017b; Yeguiayan et al., 2011). Increasing age was reported to increase mortality risk by two-folds (Chalya et al., 2012; Strnad et al., 2015). In an Indian study, no relationship between age and mortality was reported (Chandrasekharan et al., 2016). However, TBI remains a major cause of disability and death among young persons aged below 40 years around the globe (Keijzers et al., 2015).

Regarding gender, the effect on post-trauma mortality is mixed (El-Menyar et al., 2014; Falk et al., 2015). Female patients are reported to sustain more traumatic injuries than their male counterparts (Rubenson Wahlin, Ponzer, Skrifvars, et al., 2016; Trajano et al., 2014). In Tanzania, the male-to-female trauma patient ratio was 2:1 with a modal age group of 21-30 years (Chalya et al., 2012). However, in an Iranian study, males were reported to be more vulnerable to traumatic injuries than women due to their involvement in risky activities such as cycling, motoring, and violence (Norouzi et al., 2012). This was also reported by a sub-Saharan review study which found a significantly higher mortality rate among males (Boschini et al., 2016). These findings on gender roles are both mixed and contradictory. In Kenya, there is a lack of evidence to verify the role of gender in influencing outcomes and also explain any difference in post-trauma mortality.

Reviews have shown that the Glasgow Coma Scale (GCS), ISS, head computed CT scan results, and pupil reaction are other patient characteristics associated with long-term mortality

outcomes (Thompson et al., 2017a; Yeguiayan et al., 2011). In different studies, severe trauma severity and blood pressure at admission < 90 mmHg were significantly associated with post-trauma mortality (Chalya et al., 2012; Strnad et al., 2015). In a South African study, previous health conditions [co-morbidity] were found to increase mortality with an increase in patient age (Möller et al., 2018). Only one study conducted in Ghana found the level of patient consciousness to predict patients' mortality (Mahama et al., 2018).

In addition to conflicting findings on patient characteristics, reviews found no Africa-based studies examining the role of patient characteristics on mortality among TBI patients, which denotes a research gap. The effect of patient triage and hypoxemia has not been examined in African-based studies. Understanding the implications of these patient characteristics on trauma mortality is fundamental in the reduction of preventable mortality and morbidity at the prehospital care level. This study provides valuable local insight into the role of patient characteristics on survival outcomes. These findings are expected to contribute to the improvement of prehospital EMS responses for TBI and other trauma injuries in low-resource environments.

2.7 Summary of Literature Reviewed

An extensive review of published articles and grey literature on pre-hospital care, trauma outcomes, and related EMS systems globally, in sub-Saharan Africa, and in Kenya was conducted. According to the review, there are substantive knowledge and evidence gaps in three main areas: (i) the role of pre-hospital trauma care on post-trauma outcomes, (ii) the effect of health system factors on post-trauma outcomes, and (iii) local evidence on pre-hospital care response for TBI in general. Existing evidence in developing and developed countries has mainly focused on in-hospital care settings.

There are limited studies focused on understanding trauma and trauma responses in pre-hospital settings. Despite accounting for the highest proportion of preventable trauma burden, most studies available on pre-hospital settings are conducted in developed countries. This highlights the increased advocacy by WHO for developing countries to prioritize and invest in pre-hospital care research to inform locally-adapted systems and responses to trauma and injuries.

Not many studies in LMICs examine the role of health system factors, such as the role of transport modes, on post-trauma outcomes. However, the findings are both mixed and contradictory depending on study settings and context. Different countries are at different levels of health system capability and development, which explains the differences in results. Furthermore, these studies have made little to no linkage with the broader health system architecture. Pre-hospital care responses are best provided in line with "whole system" approaches since their performance and outcomes may greatly depend on other health system aspects, such as governance and leadership, financing, information, and availability of basic medical supplies and equipment. In Kenya, there is a scarcity of studies on pre-hospital trauma burden.

The patterns and effects of existing health system factors on outcomes remain poorly studied. Importantly, the role of different types of pre-hospital healthcare providers, referral systems, and interventions on post-trauma mortality, including mortality due to TBI, is undocumented. TBI contributes significantly to the trauma burden across Africa but has received little research attention. Most available studies have focused on general undifferentiated trauma. TBI has high mortality and morbidity rates and may require more organized, quality, and specific responses. This presents a significant scientific gap for researchers and policymakers.

In addition, there is limited knowledge on the role of other health system factors, such as governance, availability and management of medical supplies, the role of community interventions, and leadership on pre-hospital care systems, as well as related care outcomes. Reforms in responses, policies, and programmatic interventions will require robust, solid, and reliable scientific data to inform decisions on resource mobilization, prioritization, and performance monitoring of health systems at the pre-hospital care level. This calls for stronger and concerted efforts in making data, information, and evidence on the design, implementation, and performance of pre-hospital care systems available. As part of aligning this study with identified gaps, a systematic scoping review was conducted to map available research evidence and gaps on health systems factors associated with post-trauma mortality in African settings. The findings of the scoping review paper provided substantial insight that informed the design of this study.

2.8 General Systems Theoretical Framework

2.8.1 Overview of the Theory

This study is rooted in a system theory developed by Ludwig von Bertalanffy, which has been modified over time. This system thinking helps in understanding the complex world of organizations. Von Bertalanffy developed this theory in the 1940s and later revised it in 1976 (Bertalanffy, 1976). Ludwig conceptualized systems theory as a general science of wholeness.

The underlying assumptions of the theory are that in a complex system such as a health system, there are multiple independent and interrelated subsystems or system components that interact to create the whole complex system and its functionality. The theory criticizes closed system thinking and cause-effect relationships for their inability to appreciate and address organizational challenges or weaknesses in their wholeness, interdependence, and complexity.

It has applications in diverse fields, including psychology, health management, engineering, among other disciplines.

The main assumption of systems theory is that a complex system is made up of multiple smaller systems, and it is the interactions between these smaller systems that create a complex system. This assumption is contrary to the reductionist approach in which complex processes are dissected to study individual process components and parts separately. The systems theory by Ludwig views organizational change or reforms aimed at addressing performance issues in organizations as living systems. Like a living thing, the systems are made up of living systems and structural components whose interactions and development give them life or functionality.

Katz and Kahn reviewed the systems theory to re-emphasize the need to apply "Open Systems" introduced by Ludwig to every organization (Mele et al., 2010). This gave rise to the "Open Systems theory," which advanced systems thinking to appreciate and consider environmental contextual realities and the inter-organizational relationships that affect and influence organizational performance, including health systems, to a large extent. Katz and Kahn emphasized the need for organizations, particularly health systems, to adapt to environmental changes or contextual realities to effectively, efficiently, responsively, and sustainably deliver prioritized services in rapidly changing contexts, including legal, technology, economic, social, and health aspects.

This realist "Open systems theory" views underscores the embeddedness of smaller system concepts, parts, and processes into the larger, dynamic, ever-changing process of service planning, organization, growth, and adaptation in responding to existing, emerging, and new challenges, including legal, policy, financial, human resources, equipment, and technology. An open system such as the pre-hospital emergency care (PEC) system comprises arrangements of systems, processes, services, and personnel that are open to environmental forces or changes,

including new policies, technological adaptations, and budgetary and economic-related issues. To influence changes or outcomes of the systems, deliberate, intentional, and planned interventions are critical in mitigating or responding to these external and internal demands.

2.8.2 Relevance to the Study

Based on these theoretical assumptions, this study was anchored on the theoretical appreciation that a holistic appraisal of the PEC system components (factors) using an open health system strengthening lens is critical in improving TBI survival outcomes in out-of-hospital settings. An open systematic analysis of the interconnectedness between different health system components was done using empirical evidence to appraise existing PEC system components, their interconnectivity, and implications for TBI mortality outcomes at the PEC level.

The study was designed with an understanding that TBI mortality at the PEC level results from interactions of multiple systemic components that are interconnected and responsive to changes in the external environment, including policy and governance. These PEC factors include trauma patterns sustained by patients, access to prehospital care (which comprises prehospital transport, life-saving interventions, and EMS responders), and patient transfer or referral pathways utilized. The analytic framework considered patient characteristics and the type of tertiary hospital a patient is transferred to, which interacts with other systemic factors to influence post-trauma mortality outcomes.

The application of open health systems strengthening thinking enabled the comprehension of the relationships between these PEC systemic components and TBI mortality. This systems theory framework provided a useful analytical framework in the examination, analysis, and evaluation of the study's evidence to inform findings, conclusions, and recommendations for feasible TBI responses documented in this study.

2.9 Conceptual Framework of the Study

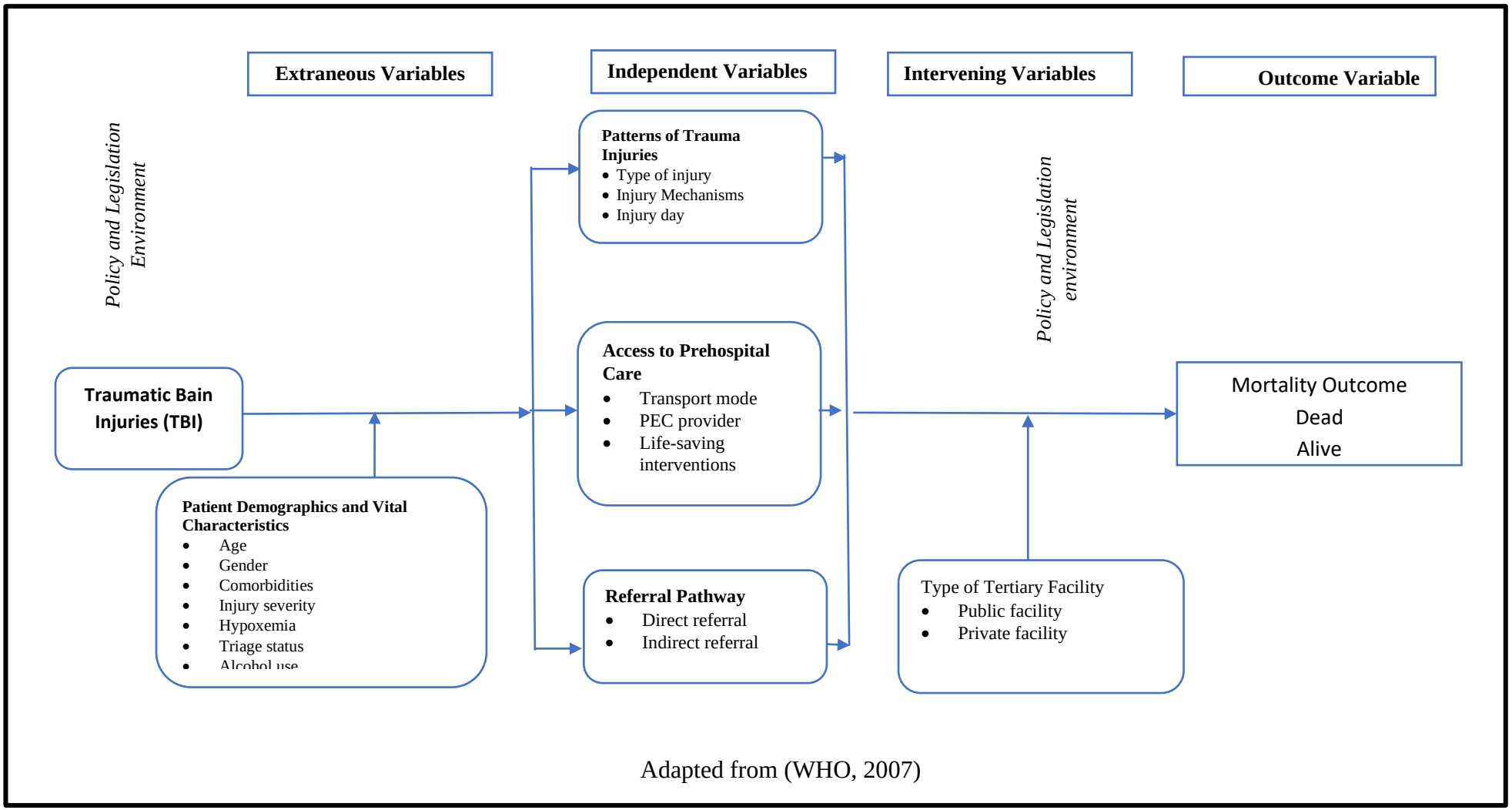
2.9.1 Overview of the Conceptual Framework

Based on systems theory and literature reviews, different PEC factors and variables were hypothesized to interact and influence TBI mortality at this level of care, including access to prehospital care and the type of patient transfer or referral systems. The review identified access to emergency care as a core PEC factor, which combines life-saving interventions provided by ambulances staffed with trained or skilled EMS providers, patient transfer pathways from the injury scene to a trauma care hospital (usually a tertiary hospital for severe cases), and the policy environment regulating the provision of PEC. These factors can all influence TBI mortality outcomes. Kenya, like other LMIC countries, faces numerous systemic gaps contributing to a significant proportion of avoidable TBI mortality, such as the quality of skilled EMS providers, ambulance capacity, and the capacity of public referral facilities to provide critical trauma care.

The review further indicates that the capacity of the PEC system to provide quality life-saving interventions is the result of the interrelations and interactions between the components of the PEC system, as articulated in the conceptual framework of the study. By addressing capacity and process gaps in these PEC components through policy or programmatic actions, the study aims to strengthen the PEC system's capacity to improve health outcomes and reduce the burden of TBI mortality. Therefore, the study hypothesizes that mortality outcomes depend on the ability of the interrelated PEC factors or components (transport, critical care such as first-aid, skilled EMS providers, timely transfer to trauma care, and supportive policy or external environment) to support efficient, effective, and responsive life-saving interventions for critical patients with TBI in these settings, both at the injury scene and en route to the trauma care hospital.

The PEC factors form the core scientific variables that underpin the conceptualization and design of this study. The review findings provide valuable insights into the conceptual relationships and how they can be modified or re-engineered to improve the quality of trauma care in Kenya and other resource-constrained contexts. For instance, the review established that PEC factors interact within a broader external environment characterized by diversity in sustained trauma patterns, patient characteristics, and the type of tertiary hospitals, which influence access to quality critical care support and related outcomes, as shown in Figure 1.1. The conceptualization of these relationships and interactions is explained below.

Figure 1.1 Conceptual Framework



Adapted from (WHO, 2007)

2.9.2 Access to Prehospital Emergency Care

In this study, access to prehospital emergency care (PEC) comprises the provision of life-saving interventions or care by trained or skilled health teams or EMS providers and rescue using ambulance transport. "No PEC" refers to patients who are not rescued by untrained lay responders and do not benefit from these services. Access to prehospital care includes three care aspects that are hypothesized to influence TBI mortality by arresting irreversible pharmacological changes.

Unlike lay responder rescue, well-equipped ambulance transport can be prompt, ensuring minimal prehospital time or delays in reaching definitive care. It provides a conducive environment, facilities, and equipment to deliver timely and appropriate life-saving interventions, such as airway management, bleeding control, medical supplies like oxygen, fluid administration, vital signs monitoring, and resuscitation on the scene, en route to the hospital, and while waiting for emergency admission at the receiving facility, among others.

2.9.3 PEC Patient Transfer Pathways

Patient transfer pathways, from the scene of the incident to a definitive trauma care hospital for advanced management and care, comprise a component factor in the PEC system that can influence care outcomes. Direct transfer to tertiary care hospitals, whether by ambulance or private transport, may reduce total prehospital time (an important mortality risk factor) and allow for advanced life-saving interventions, depending on the distance to the hospital. Indirect transfer through ill-equipped primary health facilities may result in delays in accessing appropriate critical life-saving care due to referral process delays. In other instances, this may reduce death risks where time-sensitive bleeding control and other stabilization interventions are available at these facilities. The role of the different element of the patient transfer pathway on TBI mortality was incorporated into the analytic model as part of the holistic PEC system.

Using systemic thinking, prehospital care is accessed or provided within a network of health facilities with relevant diagnostic equipment, facilities, and trained staff who provide stabilization care at the emergency departments, awaiting referral for further management or admission for definitive care. These health facilities, both primary and tertiary hospitals, provide a continuum of critical care interventions required along the referral pathways. Without these interventions, definitive care may be compromised. These facilities can be privately or publicly owned, reflecting variation in staffing, equipment, and facility capacity.

2.9.4 TBI Patterns and Patient Characteristics

Localization of PEC system interventions is a trauma mitigation strategy nationally and globally. Examining the various TBI patterns and the role of patient characteristics is essential in ensuring that the recommended interventions address TBI-specific issues and burdens. For instance, TBI mortality can vary based on sources such as RTIs (Road Traffic Injuries), versus non-RTIs, types such as blunt versus penetrative, and injury occurrence on different days (weekend or weekday).

Gender, severity, presence of hypoxemia, age, and blood pressure are some of the patient characteristics that can lower or raise the risk of death among TBI patients. For example, hypoxemic patients who have access to oxygen support may have lower odds of mortality compared to those without access. Similarly, severely injured patients with shorter prehospital times (direct ambulance transfer or referral pathway) and access to prehospital life-saving care such as resuscitation, bleeding control, and airway maintenance in well-equipped ambulances may report lower mortality risks.

Patient related factors encompass fundamental variables that can interact with broader PEC system factors to adjust mortality risks. These factors - trauma patterns and patient characteristics - were included in the conceptual model of the study to aid in explaining

adjusted mortality outcomes attributable to the PEC system factors studied. The type of tertiary transfer or definitive care facility was included as part of the PEC system in this study to help adjust the one-month period TBI mortality outcomes studied.

2.9.5 PEC Policy and Governance

The role of PEC policy/legislative and governance structures was qualitatively studied to understand the implications of quality operational context on TBI mortality using a systems thinking approach. Relevant policies and governance structures provide the necessary mandates, resources, and accountability frameworks for a functional PEC system. A functional policy and effective leadership structures give life and meaning to reform initiatives or recommendations aimed at improving access to and outcomes of prehospital care.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This section provides a detailed explanation of the methodology used in the study to achieve its main objective of determining the relationship between prehospital care factors and TBI mortality in Kenya. It covers various aspects such as the study design, study settings, sample size determination and sampling procedures, study variables and measurements, data tools, consenting, data collection procedures and quality assurance processes, ethical considerations, data management and analysis, study results dissemination plans, and limitations.

3.2 Study Design

The study utilized a retrospective case-control study design that incorporated multiple approaches to collect, organize, and analyze retrospective data. The retrospective design involved the collection of longitudinal data by looking back and examining exposure or mortality protection factors (PEC factors) in relation to the study outcomes, specifically TBI mortality. The three approaches used to collect data were scoping review, retrospective data collection (quantitative), and qualitative methods, which are described below.

3.2.1 Scoping Review

A scoping review was conducted to investigate the health system factors associated with post-trauma mortality at the prehospital care level in Africa (Koome et al., 2020). The findings of this review were integrated into the study, helping to map existing evidence and identify research gaps that the retrospective study aimed to address. The review's findings have also been incorporated into the literature review section of this study.

3.2.2 Un-matched Case-Control.

This approach involved the retrospective abstraction of data (quantitative and qualitative) from patient medical records in the selected health facilities. In this study, cases were patients who had died within one month after sustaining a TBI, while controls were patients who were alive within the same period. Unlike a matched case-control design where controls are selected based on specific characteristics such as age and sex, an un matched case-control design randomly selects a shared control group for all cases, differing in certain attributes. In this study, controls for the selected cases were randomly sampled from a group of eligible controls without matching their social-demographic and clinical characteristics (such as age, sex, trauma severity, hypoxemia, comorbidity, etc.) to the cases. This design was chosen due to difficulties in identifying exposed subjects or controls with similar characteristics as the cases from the same facility.

3.2.3 Qualitative Approach.

Qualitative data obtained from key informant interviews were used to complement the quantitative data using convergent triangulation methods (Bowling, 2001). In this design, both quantitative and qualitative evidence is collected and analyzed simultaneously, complementing each other. A result-based analytical approach was employed to analyze both datasets separately and later integrate them. The integration process focused on identifying patterns and linkages in thematic insights to explain the analytical outcomes.

This approach enhanced the validity and reliability of the findings by minimizing potential biases associated with using only one data method, such as selection/sampling bias and recall bias. It also facilitated the generation of deeper insights and explanations of the findings and supported objective convergent inferences on similar study concepts or issues (Bowling, 2001).

3.3 Sampling and Sampling Procedures

3.3.1 Study Settings

The study was conducted in Kenya, a country with an estimated population of 47.6 million in 2019 (Kenya National Bureau of Statistics, 2019). The majority of the population in Kenya is comprised of young people below 35 years, accounting for approximately 75% (Kenya National Bureau of Statistics, 2019). However, nearly half of the population (46%) lives in poverty, with limited access to quality health care, including emergency life-saving interventions. Despite commendable progress over the last two decades, the prehospital care system in Kenya remains weak, unable to adequately respond to the increasing health risks and challenges, including the COVID-19 pandemic, that threaten the well-being of its citizens.

3.3.2 Selection of Study Sites/Facilities.

The study was conducted in three trauma referral hospitals located in Kiambu and Nairobi Counties, namely: Kikuyu Mission Hospital (private) in Kiambu, Mater Misericordiae Hospital (private), and Kenyatta National Hospital (public) in Nairobi. These hospitals were purposively selected because they cater to a significant number of low- and middle-income patients seeking care in both public and private health facilities. According to the Kenya Master Health Facility List in 2020, the MoH accounts for approximately 42% of the total health facilities in the country, while the private sector accounts for 38%, mostly in urban areas.

Due to the higher vulnerability to TBI among ordinary low-income Kenyans, public tertiary hospitals like Kenyatta National Hospital attend to about 70% of TBI cases in Kenya. These selected hospitals represent the most vulnerable population to TBI risks at the prehospital care level. The choice of these facilities was based on factors such as their location in highly urbanized areas with high motorization rates, access to large volumes of TBI caseload datasets

compared to other counties and rural settings, and the availability of electronic medical records databases for ease of access and retrieval of eligible cases.

3.3.3 Selection of Study Population.

The primary study population consisted of TBI patients admitted to the three trauma referral facilities between January 2019 and March 2019. Cases and controls were defined based on their post-trauma mortality outcomes at the facility level. Cases were patients who had died within one month after sustaining prehospital trauma injuries, while controls were patients who were alive within the same period.

3.3.4 Sample Size Determination

To determine the sample size for the study, the sample size determination formulae for a retrospective case control study (Sharma, 2015) shown below was applied . The sample size was derived and validated using the online OpenEpi software. The proportion of cases exposed was estimated to be at least 60%, and the odds ratio was set at 2.0. The sample size calculation resulted in a total of 308 pairs (154 cases and 154 controls).

$$n = \left(\frac{r+1}{r}\right)\frac{(\bar{p})(1-\bar{p})(Z_{\beta}+Z_{\alpha/2})^2}{(p_1-p_2)^2}$$

Where,

n	sample size in the study group
Z_{α}	the probability of type I error (significance level). This is the probability of rejecting the true null hypothesis, set as 0.05; typically, 1.96 for 0.05.
z_{β}	the probability of type II error (1 - power of the test). This is the probability of failing to reject the false null hypothesis, set as 0.20 for a desired power of 80%
P_1	the proportion for cases, generated by the software as 0.6667

P_2	the proportion for controls, set at 0.6. The proportion exposed in the control group is estimated to at least 60% (Oliver et al., 2017a).
OR	the calculated odds ratio, set at 2.0
r	the ratio of case-control (1 case/r controls), set at 1.0

In this study, the proportion exposed in the control group is estimated to at least 60% (Oliver et al., 2017). To get proportion of cases exposed (With expected Odds Ratio of 2.0):

$$p_{case\exp} = \frac{ORp_{control\exp}}{p_{control\exp}(OR-1)+1}$$

$$p_{case\exp} = \frac{2.0(.6)}{(0.6)(2.0-1)+1} = \frac{1.2}{2.8} = .15$$

Therefore, the average proportion of cases exposed = (.08+.15)/2=.43

$$n = 2\frac{(.43)(1-.43)(.84+1.96)^2}{(.43-.6)^2} = 154$$

The sample size (n_{pairs}) = 308 (154 cases, 154 controls)

Section 3.4.1 provides details on selection of cases and controls in this study.

3.3.4.1 Inclusion Criteria.

The study included patients aged 18 years and above with confirmed cases of TBI based on the Disease Classification Systems (DCS) codes assigned to their medical files by health care professionals during the documentation process. The specific DCS codes used for identifying and classifying TBIs are provided in Appendix 7. Only patients admitted between January 2017 and March 2019 were included in the study.

3.3.4.2 Exclusion Criteria

A total of 431 patients were excluded from the study based on the following criteria:

i. Patients confirmed dead at the injury scene. as data on patients who died at the scene whereas obtained from admission registries ambulance records, and death notification forms.
ii. Patients who were not transferred to the emergency department from the injury scene, including those taken directly to the morgue, as collecting data and records for these cases was challenging and not well-documented in hospital registers or information systems.
iii. Patients not admitted to the trauma care facilities within a month after the injury, particularly, those with minor injuries that did not require admission and whose prehospital care would not significantly impact their survival.
iv. Patients transferred from a referral facility to another facility or referred from lower trauma care facilities after at least twenty-four-hours of admission to avoid bias related to differences in the quality of care between in the referring and receiving facilities.
v. Patients with a history of severe or multiple life-threatening injuries (poly-trauma), as this increases the risk of mortality.

3.3.5 Allocation of Cases and Controls

The primary source of data for this study was patient medical records, and files were sampled based on disease diagnosis codes (DCS) assigned to each patients file obtained from in-patient admission files or Emergency Department (ED) Registers. The DCS for TBIs used in this study can be found in Annex 7. An excel sheet was created for each hospital, separately compiling a list of cases and controls that met the eligibility criteria. Random numbers were generated using

the excel list for each hospital to select proportionate samples for each hospital, as shown in Table 3.1. To avoid selection bias caused by sampling more patients from either public or private tertiary hospitals, a proportionate sampling approach was used to allocate the sample to the three facilities, as described in Table below.

Table 3.1 Sample and Sample Size Allocation

Hospital Name	Controls	Cases	Total
KNH [Public]	67 (40%)	100 (60%)	167 (53%)
Misericordiae Hospital [Private]	36 (75%)	12 (25%)	48 (15%)
Kikuyu Hospital [Private]	55 (54%)	46 (46%)	101 (32%)
Totals	**158 (50%)**	**158 (50%)**	**316 (100%)**

3.3.6 Selection of Key Informant Interviews

In addition to quantitative findings, the study also included qualitative information obtained from purposely selected key informants, which included prehospital care providers and policy makers (see list of key informants in Appendix 8). A total of 38 key informants were selected for this qualitative data, representing key actors from relevant organizations involved in prehospital EMS care services. The selection of key informants was based on their position, expertise, and knowledge in pre-hospital trauma care and health system settings.

The key informants were selected from various disciplines related to the study, including policy, regulatory, service delivery, and re response systems. These institutions included lower

trauma and referring hospitals, Ministry of Health (MoH), Kenya Council of Emergency Medical Technicians (KCEMT), Non-Governmental EMS providers like St. Johns Ambulance, professional healthcare providers, paramedics, and health system policy researchers or practitioners. The position, ranks, and roles of the key informants interviewed are detailed in Annex 8.

The selection of key informants considered their practice experience and knowledge of pre-hospital trauma care, ensuring a comprehensive insight into health system factors and interaction points from a health systems perspective. Although not all targeted key informants were interviewed due to achieving saturation point, most of the scheduled interviewees were reached and interviewed. This decision was made to uphold ethical considerations and ensure the inclusion of diverse stakeholder views on the study outcomes. These key informants helped collect detailed data and information on study outcomes, providing additional perspectives to complement the quantitative findings derived from the retrospective abstraction of medical records data.

3.4 Study Variables

3.4.1 Dependent Variable

The dependent variable of the study was mortality after a TBI in out -of- hospital settings. Mortality was defined based on a 30-day post-trauma mortality outcome. Mortality outcome was categorized as either patients' death or survival. Discharge data from electronic health information management systems at the facility level, along with discharge records from manual patient medical files, were used to determine the mortality status.

3.4.2 Independent Variables.

The study examined trauma patterns and three health system factors as independent variables. These variables are explained below:

i. **Trauma pattern:** This refers to the various ways trauma is presented or the characteristics of the injury. The injury characteristics studied included the type of injury (penetrating /blunt), the mechanism of injury such as road traffic incidents/non-road traffic incidents like violence, falls and gunshots) and the day of injury (weekday: Monday /Tuesday /Wednesday/Thursday or weekend; Friday/ Saturday/Sunday). The weekend was defined to start on Friday, specifically from Friday afternoon when there is a sudden increase in socialization and other activities like drinking, holidaying and group-based activities.

ii. **Prehospital care:** This involved access to prehospital emergency care (PEC) provided through ambulance services by trained or skilled EMS (Emergency Medical Services) providers. The responses were coded as either Yes (PEC) accessed) or No (PEC not accessed. To simplify recoding of this composite variable, the following aspects of PEC were defined as follows:

   a. Access to life-saving intervention: This included a r range of Basic Life Support (BLS) services and where available, Advanced Life Support (ALS) services provided by skilled health professionals or EMS providers. The Responses were coded as Yes (received any intervention) or No (did not received any intervention).

   b. Type of EMS responder or provider: This refers to the different types of responders involved in prehospital care. The variable examined the various

categories of EMS providers commonly involved in emergency responses at the prehospital care level. Three categories were adopted: (i) paramedics – trained or skilled medical personnel specializing in emergency responses and care in out of hospital settings, (ii) facility-based clinical staff (such as nurses and clinicians providing skilled facility-based or out of hospital medical care), and (iii) untrained lay responders – untrained and unskilled in emergency care often referred to as good Samaritans.

c. **Type of Pre-Hospital Transport Mode:** This refers to the different modes of transport used to transfer trauma patients from the injury scenes to the emergency departments in receiving hospitals. This variable studied two main forms of transport ambulatory and non-ambulatory, Ambulance transport involved patient transfer using public and private-owned EMS ambulances while non-ambulance transport mode involved patient transfer using means other than ambulances such as private cars, public vehicles, taxis, walk-ins, motorbikes and carts.

iii. **Type of Pre-Hospital Referral Pathways:** This refers to the transfer protocol used to refer or transport a patient from an injury scene to a specialized trauma care facility. It includes, direct and indirect referral. Direct referral pathway involves transferring patients directly from the injury scene to a specialized trauma care facility without passing through lower-level facilities. Indirect referral refers to transferring patients to a specialized trauma care facility through lower-level health or peripheral facilities.

3.4.3 Confounder Variables

In this study, a statistical correction method was employed to identify potential confounders, which are factors or variables that can influence or create a spurious association, affecting both independent and dependent variables. A difference of at least 10% between adjusted and

non-adjusted regression coefficients was used to confirm confounding (Lynch, 2013; Pourhoseingholi et al., 2012). This method was complemented by assessing statistical significance at a 0.05 level between the variables and mortality outcome (Lynch, 2013). Using this approach, the type of referral facility (public/private) a patient is transferred to after an injury and the trauma severity score (severe/moderate/mild) were identified as potential confounders in the study. Adjusted logistic regression (explained in Section 3.9.2), a statistical correction method, was utilized to control for these confounders, as well as other extraneous variables described below.

3.4.4 Extraneous Variables

The study acknowledged and controlled for extraneous variables that could potentially lead to incorrect or inaccurate statistical conclusions regarding the impact of PEC factors on TBI Traumatic Brain Injury) mortality. These variables consisted of patient demographic and vital or clinical characteristics that have the potential to influence the accuracy of analytical outcomes or models. Specifically, the variables included:

a) **Patient demographic characteristics:** These comprised patient age (18-29 years, 30-39 years, 40-49 years, 50-59 years, 60+ years) and gender (male, female).
b) **Patient vital or clinical characteristics:** These included the Glasgow Coma Scale GCS) Score (severe, moderate and mild), presence of hypoxemia (yes/no), presence of comorbidity (yes/no), alcohol use (yes/no), patient triage status (Emergency, urgent and not urgent) and blood pressure levels (hypertension, elevated and normal).

3.5 Data Collection and Consenting Process

3.5.1 Quantitative Data from Medical Records

Medical records data comprised a significant source of abstracted data in this study. Hospitals and EMS providers routinely collect and collate pre-hospital trauma data using multiple records including trauma registries and records in the A&E at the facility level, ambulance records and referral notes. Cases and controls were identified and recruited based on diagnostic codes assigned to their medical records in the selected facility. These codes were compiled from trauma patient registers or files archiving in the emergency department in the chosen hospitals.

The following procedure was applied in abstracting this data:

Step 1: Upon receiving ethical approval of the study, written Institutional Ethical Board [IEB] approvals [Appendix 9-15] to conduct data including access to patient records and abstraction of data] in the facility were obtained. The written approval enabled access to data and cooperation from relevant departments and staff in the selected facilities.

Step 2: Using the list of eligible cases and controls selected using sampling procedures stipulated in Section 3.4.2. (a) using an electronic medical records database in the facility, the selected patient medical records or files were obtained from the filing areas for data abstraction. In every hospital, an experienced Health Records and Information Officer [HRIO] was recruited, oriented and contracted to assist in quick retrieval of the sampled records from the filling section.

Step 3: A pre-tested medical records review form (
Appendix 1 Records Review Forms) was used to review and abstract medical data for the study. Details of data abstracted are outlined in Section 3.6.1 (a) while details of

pre-testing are provided in Section 3.7.2 Quality . Trained research assistants assisted in abstraction of data from the medical records. Data abstraction was done within the hospital premises – no file was taken out of the hospital. A suitable separate room or work-space was provided by the Health Information Department from where retrieved patient records were reviewed and data abstracted. This was part of confidentiality and privacy measures aimed at avoiding unintended exposure of confidential patient medical data.

Step 3: Stringent measures were undertaken to ensure quality and reliability of data collected. To improve completeness and accuracy of abstracted data, ambulance run sheets, referral notes, trauma registries at the A&E department and patient mortality reports such as death notification forms were used to complement patient medical records data. For instance, data on patient who died at injury scene was obtained from admission registry and ambulance records complemented by death notification forms. Triangulation of data from multiple sources enhanced the integrity and quality of data collected. In addition, the principal investigator provided close supervision of the field work in all the study sites. See detailed quality assurance measures in Section 3.6.5

Because the study involved de-identified retrospective data abstracted from many patient records - some of whom were deceased - it was difficult to reach and contact all the respondents and obtain informed consent, particularly, the deceased. A waiver of consent for data abstraction was granted by Ethical Review Committee (IRC) [*KNH-UoN/ERC/FORM/IC05*] and respective Institutional Review Boards (IRB) at the facility level. A copy of the consent waiver certificate is provided as Appendix 9. Annex 10-15 provides evidence of relevant institutional approvals for the data collection.

3.5.2 Qualitative Data from Key Informants

Primary qualitative data was collected from purposively sampled key informants to gain further insights into the findings of the quantitative study by utilizing triangulation approaches. The qualitative data collection process involved the following steps:

The qualitative data collection process involved the following steps:

Step 1: Key informants were selected purposefully using the qualitative sampling procedure and criteria explained in section 3.4.2.

Step 2: Written informed consent was obtained following the procedures outlined in section 3.6.2. (b)

Step 3: After obtaining informed consent, the principal researcher prepared an interview schedule indicating the interviewee codes, preferred interview method, time, and venue. Interviewees were given the freedom to choose the interview venue and time to ensure interviewees to participate, resulting in a 100% participation rate among those who agreed privacy and convenience. This approach increased the willingness and ability of potential to take part. The scheduled interview time was communicated to each participant, and reminders were provided.

Step 4: The interviewees were conducted using different methods based on the preferences of the key informants, two main methods were used;

1. Face-to-face or physical interview which was undertaken within interviewees' work place usually in a room or office of choice. choice. In some cases, a separate private room was used to ensure confidentiality. The study revealed that discussions on pre-

hospital care practices and emergency care are sensitive and can involve criminal aspects related to lapses in care processes, including delays in treatment. Due to this, sensitivity respondents many respondents preferred private They also declined to consent to an audio recording.

2. Virtual interviews were conducted through phone and Skype calls. This method was chosen by a few respondents who had difficulty finding time for a physical meeting due to work and or travel schedule. Respondents were requested to schedule interviews during free time and possibly, allocate at least 45-60 minutes for an in-depth discussion. Virtual calls were mainly conducted in the mornings, during lunch or evening but based on individual preferences to ensure adequate time for discussions.

Step 5: The interviews used pre-tested interview guides (Appendix 2) to conduct key informant interviews. To facilitate structured and insightful discussions, interview guides were shared with respondents at least two days prior to interview. Where permitted, voice recorders were used to record interviews for detailed analysis with interviewee's written permission (consent) to use audio recorders (Annex 21). However, 29 interviewees declined audio recordings due to the sensitivity of pre-hospital patient care and outcomes. In such cases, research assistants took manually summarized notes during the interviews. Both the manual notes and transcribed audio scripts were de-identified using unique codes. At the end of each interview, summary notes were reviewed, and key points. key points were documented to avoid loss of valuable data and information.

Step 6: During field work, each interview process and response were summarized, studied and used to improve subsequent interviews, as needed.

Regarding the consenting procedure, written informed consent was obtained from all participating key informants prior to conducting in-depth interviews. The principal researcher, assisted by trained research assistants, followed these steps:

Step One: The principal researcher and research assistants, explained the study to the sampled participants verbally, providing all pertinent information (purpose, procedures, risks, benefits, alternatives to participation, etc.). all participants were allowed the opportunity to ask questions, seek clarifications and make informed decisions.

Step Two: A written adult participant information and consent form adopted from KNH-UON website (KNH-UON, n.d.) and with similar information detailed in step one was used to complement verbal explanations and guide the process. Interviewees were accorded sufficient time to consider whether or not to participate in the study. Time ranged from thirty minutes to seven (one week) days depending on individual needs and requests for more time. The aim was to accord the interviewees a reasonable time to understand and evaluate the procedures, risks, potential benefits, and potential alternatives in making a decision on participation.

Step Three: The principal researcher met with the interviewees either physically or through phone or Skype calls to answer any additional questions they may have had. This meeting also served to obtain written consent from those who agreed to participate.,.

Step Four: Both the interviewee and principal researcher signed a dated written informed consent document to confirm their participation in the study. In most instances, the interview schedule coincided with signing of the consent form.

Participation in the study was voluntary. Participants had the latitude of withdrawing from the study at any time of the study without any negative consequence. However, no interviewee withdrew from the interview after acceptance to participate. There was also no incidence of declined interview requests by the selected key informants.

Details about the procedures for analyzing the quantitative and qualitative data can be found in section 3.8 of this chapter.

3.6 Data Collection Tools

The study utilized both secondary and primary data. Secondary data was obtained by abstracting information from medical records, while qualitative data was collected through interviews with selected key informants. The description of the data tools and collection procedures is provided below.

3.6.1 Data Abstraction Forms

Secondary data was abstracted from patient medical records at the trauma care facility. A pre-tested form, called the Records Review Forms (see Appendix 1) was used to review and extract data from the records of sampled patients. The abstracted data included patient demographics and vital characteristics such as age, comorbidity, consciousness, triage status, Glasgow Coma Scale (GCS), trauma patterns, and health system related data like transport modes, referral pathways and facilities used. Additionally, patient mortality outcome (death or survival). was recorded.

To ensure the completeness and accuracy of the gathered data, other pre-hospital care records such as ambulance records, referral notes and trauma registries maintained at the Accident and Emergency Departments were also consulted Patient registers at the facility provided additional valuable information ,including specific injury details patient demographics, survival status

and trauma characteristics like injury place, injury time, transport means, and details about care providers or rescuers. For deceased patients, mortality and death notification reports were used to gather information on the cause, time, and demographics of the patient. The record review form captured the following data details:

1. In-hospital trauma mortality outcomes (death or survival)

2. Trauma patterns, including the day of injury, type of injury, and injury mechanism (e.g., road traffic accidents, falls, gunshots, violence)
3. Health system-related factors, such as types of pre-hospital care providers (paramedics, lay responders, facility-based staff), transport modes (ambulance and non-ambulance), type of interventions administered in the pre-hospital care settings (Basic Life Support, Advanced Life Support, no care), and the referral pathway used (direct or indirect)
4. Patient casualty characteristics, including patient demographics (age and gender) and vital characteristics such as GCS, oxygen concentration, and blood pressure levels.

3.6.2 Key Informant Interview Guides

Key informant interview guides were used to collect data from various stakeholders. These guides were pre-tested and tailored to each category of stakeholders to ensure in depth discussions on specific subjects relevant to them Four types of interview guides were used for facility actors, EMS providers, health insurance providers, government actors, and subject matter experts.

The key informant guide included questions about patterns of trauma and related outcomes, types of pre-hospital transport and evacuation systems, types of pre-hospital care interventions, types of pre-hospital EMS providers and types of pre-hospital referral pathways. The interview also explored contextual health system factors such as pre-hospital care financing, legislation

and regulation, leadership and governance, EMS coordination, and opportunities for addressing identified gaps. The interview process employed investigative questions to gather further information and insights on the studied issues and concepts (Bowling, 2001). Probing questions were used to clarify and verify interviewees'' views, opinions, and statements, thereby enhancing objectivity and impartiality in the analysis, interpretations, and conclusions

3.7 Training and Quality Assurance

3.7.1 Training of Research Assistants

The training of Research Assistants (RAs) was conducted as part of the data quality control and assurance measures. Four experienced RAs with clinical-related degrees were recruited and trained to assist in the medical records review. The research assistants included two nurses, one clinical officer and one Health Records and Information Officer (HRIO). These RAs had over two years of hands-on experience in similar care delivery processes and outcomes, which enhanced their ability to comprehend, review and extract relevant data from medical documents. The HRIO played a key role in sampling and retrieving medical records using appropriate diagnosis codes assigned to patient files ensuring that only relevant files and diagnosis codes (TBIs) were included in the sampling frame, review and abstraction process. The recruited RAs had at minimum of two years of experience in field data collection, specifically in medical records data abstraction, which was a mandatory requirement. These qualification requirements ensured that the research assistants possessed the necessary knowledge, understanding and skills to abstract high-quality data.

A four-day training workshop was conducted to instruct and guide the data collection team. The training modules focused on the study's purpose, objectives, and outcomes, data collection methodology, sampling and consenting procedures, and ethical considerations. Mock sessions and role plays were incorporated into the training to ensure optimal transfer of skills and

knowledge to the team, as illustrated in the training schedule provided in Appendix 16. The mock sessions allowed for pre-testing of the study tools including mock patient file reviews and actual interviews with key informants as described in Section 3.7.2 Quality Assurance Procedures. The training was conducted by two facilitators: the principal investigator and a practicing physician trained in critical trauma care. The physician brought firsthand experience in trauma care and research involving medical records review for trauma cases.

3.7.2 Quality Assurance Measures

Confounding factors pose a significant challenge to the validity and reliability of observational studies. In similar studies, age and injury severity have been identified as potential sources of confounding. In this study, we hypothesized that the type of in-hospital care facility could also be a confounding factor due to differences in the quality of care provided by privately and publicly owned or funded facilities. To mitigate the risk of not accounting for potential confounders, we used a logistic regression model that included all patient characteristics, thus controlling for confounders and other potential confounders in the analysis.

In addition to employing standardized data collection tools, we employed data and method triangulation to enhance the quality of our results. Qualitative and quantitative data were used in combination to complement each other. We consulted multiple data sources, such as trauma registers at the A&E, to verify, validate, and supplement the abstracted data. We developed standard data collection tools, including key-informant interview guides and data abstraction guides, to ensure adherence to acceptable collection processes and standardization. This approach minimized variation in responses and facilitated focused discussions. These measures were implemented alongside a 4-day training program for experienced research assistants who possessed sufficient basic knowledge and understanding of the research subject matter.

During the training, we conducted a pre-test of the tools in a county- level 5 hospital to enhance the validity and reliability of both the study tools, datasets, and findings. The selected county hospital for the pre-testing had advanced critical trauma care facilities providing a suitable context for the pre-test. We pre-tested the records'' review form using a sample of 30 anonymized study files.

To further validate the abstracted data, we conducted a total of eight mock key informant interviews, with each research assistant conducting two interviews. Additionally, we had two trained research assistants independently abstract data from a, single medical file, and their entries were compared. The principal investigator (PI) reviewed the final datasets and level of agreement in the results, discussing any inconsistencies with the team and agreeing on how to address them. The PI developed agreement scores using a standard scoring matrix, which guided the corrective actions taken for areas with inconsistencies or variations. To ensure consistency and accuracy in data entry and capture, the principal investigator also randomly sampled and reviewed the entered data.

Supervised data abstraction was another measure we implemented. The principal investigator conducted random reviews of individual research assistant work on a daily basis. including re-abstracting a random sample of the reviewed documents for result comparison. During these audits, any gaps in practice or outcome whereas identified, discussed, and addressed as necessary. Two of the research assistants also performed supervised data -entry into a pre-defined Excel sheet workbook, receiving training on the workbook to ensure high quality data entry.

In addition to employing standardized data collection tools, we employed data and method triangulation to enhance the quality of our results; qualitative and quantitative data were used to complement each other. Multiple data sources such as trauma registers at the A&E were

consulted to verify, validate and complement abstracted data. Standard data collection tools such as key-informant interview guides and data abstraction guides were developed to ensure adherence to acceptable collection processes and standardization. This minimized variation in responses and allowed a focused discussion. These measures were in addition to 4-day training of experienced research assistants with adequate basic knowledge and understanding of the research subject matter.

During the training, pre-testing of the tools in a county, level 5 hospital was done to enhance validity and reliability of both study tools, datasets and findings. The county hospital used for pretesting provides advanced critical trauma care, hence providing suitable pretesting context. The records' review form was pre-tested using 10% of study sample files, that is, 30 files. The files were anonymized for training purposes.

A total of eight (8) mock key informant interviews were also done; that is, two per RA. To further validate the abstracted data, single medical file was abstracted, and data entered by two trained RA. The final datasets and level of agreements in results was reviewed by the PI, discussed with the team and agreement on how to resolve inconsistencies agreed upon. The PI developed agreement scores using a standard scoring matrix which were used to inform the corrective actions on data capture areas with inconsistencies or variations. Random sampling and review of the entered data was also undertaken by the principal investigator to ensure consistency and accuracy in data entry and capture.

Supervised data abstraction was also applied. During data abstraction, the principal investigator conducted random reviews of individual RA work every day. This included re-abstracting a random sample of the reviewed documents and comparing the results. During this audit or review, any gaps in practice or outcome was identified, discussed and any corrective action undertaken. Supervised data-entry into a pre-defined excel sheet workbook was also

undertaken by two of the research assistants. An orientation or training was done to the RA to ensure quality of data entry.

We also incorporated regular expert consultations, including study supervisors and external experts, to ensure the appropriate analytical processes, procedures, and techniques were adopted and applied consistently. This enhanced the robustness and soundness of the study methodology. In cases where data was missing, data imputation was performed after verifying that the missing data was absent from the data abstraction forms and resolving any omissions. Besides input from other study supervisors, an experienced and skilled biostatistician provided valuable statistical guidance and input throughout the analytical processes to ensure the methods were robust and aligned with the study objectives and protocol.

3.8 Data Management and Analysis

3.8.1 Quantitative Data

Quantitative abstracted data was compiled, coded, entered, and cleaned using IBM SPSS version 26, which is a data analytic software. To ensure data accuracy, each data set was entered by two individuals, allowing for validation and resolution of any inconsistencies. This process addressed issues such as data capture inconsistencies, missing data, and incomplete data.

Before analysis, the data was explored and pre-analyzed to ensure its suitability for the analytical techniques used. For logistic regression analysis, model calibration assessment was conducted to identify relevant model parameters and ensure data fit. The goodness of fit test was used to evaluate the calibration of the prediction model and determine its adequacy. This test was used to determine how well the model fits the observations for binary outcome analysis. The. validation of predicted variables (classification rates) was also used as a

diagnostic test. The test results for each model performed are presented along with the model results in the findings.

In this study, collinearity was tested using Variable Inflated Factor (VIF) in SPSS. Multicollinearity is indicated by a VIF of 5 or above and/ a tolerance level of less than 0.20 (Daoud, 2018). None of the variables in the model showed multicollinearity or heteroscedasticity effects.

To describe patient characteristics, trauma patterns, and various health system factors studied, descriptive statistics such as frequencies, percentages, means, and standard deviations were applied. Continuous variables were described using means and standard deviations, while categorical variables were described using frequencies and percentages. Bivariate analysis was used to assess differences in mortality outcomes based on patient characteristics and selected health system factors of interest. Pearson's chi-square test was used to assess differences in proportions, and independent t-tests were used to assess differences in mean patient ages.

Logistic regression, a multivariate analytic model, was used to assess the association between mortality, trauma patterns, and prehospital emergency care (PEC) factors, while adjusting for other predictor variables. The choice of this model was based on its ability to control for confounders, consider moderating or extraneous variables, and classify and predict PEC factors that are essential in mitigating avoidable traumatic brain injury (TBI) mortality burden.

A confounder is a variable that is significantly associated with both the exposure and outcome. The presence of confounders in a model can affect the variables being studied, leading to results that do not reflect the actual relationship. To identify confounders, the Mantel-Haenszel statistical test was used. This test compares, crude Odds Ratios (OR), calculated without stratifying with stratum-specific OR. Homogeneity of effect estimates across strata was assessed by comparing stratified and un-stratified ORs. If the effect estimates are roughly

homogeneous and do not differ significantly from the whole group estimates, there is no confounding.

If the effect estimates are considerably similar across strata but differ from the whole group estimates by more than 10%, confounding is confirmed. Additionally, a logit model was used to identify possible confounders by examining a 10% difference between adjusted and unadjusted regression coefficients. The statistically significance at a 0.05 level between exposure and outcome was also taken into account to confirm confounding.

Based on previous studies and literature, variables such as patient age, sex, total prehospital time and presence of comorbidity were adjusted in the logistic regression model as potential confounders. The two study confounders and other statistically significant patient-related characteristics identified during bivariate analysis were included or adjusted for in the regression model as possible confounders, using adjusted odds ratios to report the statistical findings.

In this study, the outcome variable (mortality) was dichotomous defined as 0 for not experiencing an event (survival) and 1 for experiencing the event (mortality). The logit (logistic) model was used to estimate the log odds of TBI mortality based on a set of explanatory factors. The error term in the model is represented by the symbol 'ei'. The logit model used in this study developed by (Menard, 1995) is expressed as follows

$$\begin{aligned} \ln(Y') &= \text{logit}\left[\pi(x)\right] \\ &= \ln\left(\frac{\pi(\underline{x})}{1-\pi(\underline{x})}\right) \\ &= \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p \quad + \text{ei} \end{aligned}$$

In this study, the hypothesis was that the independent variables, namely, trauma patterns, access to prehospital care interventions and type of referral pathway used do not influence TBI

mortality after adjusting for other variables. In estimating the relationship between patient's characteristics and TBI mortality, the logit of the model, that is, mortality (p) was estimated as shown in equation (1):

$$\text{Logit}(p) = [\alpha_j + \beta_{1*}\text{age} + \beta_{2*}\text{gender} + \beta_{3*}\text{hypoxemia} + \beta_{4*}\text{co-morbidities} + \beta_{5*}\text{ trauma severity } \beta_{6*}\text{blood pressure} + \beta_{7*}\text{triage status} + \beta 8_{*}\text{alcohol use}] + \beta_{9*}\text{type of trauma care facility} + ei \quad (1)$$

In estimating the association between trauma patterns and TBI mortality, the logit model, that is, mortality (p) was estimated as shown in equation (2):

$$\text{Logit}(p) = [\alpha_j + \beta_{1*}\text{age} + \beta_{2*}\text{gender} + \beta_{3*}\text{hypoxemia} + \beta_{4*}\text{co-morbidities} + \beta_{5*}\text{ trauma severity } \beta_{6*}\text{blood pressure} + \beta_{7*}\text{triage status} + \beta 8_{*}\text{alcohol use}] + \beta_{9*}\text{type of trauma care facility} + \beta_{11*}\text{trauma mechanism} + \beta_{12*}\text{type of injury} + \beta_{13*}\text{injury day}] + ei \quad (2)$$

In estimating the effect of access to PEC on TBI mortality, the logit of the model, that is, mortality (p) was estimated as shown in equation (3):

$$\text{Logit}(p) = [\alpha_j + \beta_{1*}\text{age} + \beta_{2*}\text{gender} + \beta_{3*}\text{hypoxemia} + \beta_{4*}\text{co-morbidities} + \beta_{5*}\text{ trauma severity } \beta_{6*}\text{blood pressure} + \beta_{7*}\text{triage status} + \beta 8_{*}\text{alcohol use}] + \beta_{9*}\text{type of trauma care facility} + \beta_{10*}\text{access to PEC}] + ei \quad (3)$$

In estimating the effect of patient transfer pathway and type of trauma care facility on mortality, the model logit, that is, mortality (p) was estimated as shown in equation (4):

$$\text{Logit}(p) = [\alpha_j + \beta_{1*}\text{age} + \beta_{2*}\text{gender} + \beta_{3*}\text{hypoxemia} + \beta_{4*}\text{co-morbidities} + \beta_{5*}\text{ trauma severity } \beta_{6*}\text{blood pressure} + \beta_{7*}\text{triage status} + \beta 8_{*}\text{alcohol use}] + \beta_{9*}\text{type of trauma care facility} + \beta_{10*}\text{type of pre-hospital referral pathway}] + ei \quad (4)$$

In this study, we reported the Adjusted Odds Ratio (AOR) for TBI, controlling for possible confounders such as age, gender, trauma severity, hypoxemia, comorbidity, total prehospital time, type of transfer tertiary facility, and access to PEC. Statistical significance was inferred at a 0.05, level, corresponding to 95% Confidence Interval (CI).

3.8.2 Qualitative Data Analysis

Qualitative data was thematically analyzed using Nvivo software. Any recorded audios were transcribed into written soft-copy scripts. The transcripts and interview summary notes were coded into themes and sub-themes using a hybrid coding system that combines pre-set and emerging coding themes. Emerging themes represent codes that were not anticipated during the coding process. The themes were analyzed to identify new insights, patterns and relationships between health system factors at the prehospital care level and mortality.

Qualitative analysis can be influenced by the subjectivity of the researcher, introducing potential bias (Flemming et al., 2016; Ochieng, 2009). To mitigate this risk, the study employed data triangulation using different information sources, comparing themes, and involving two separate qualitative data analysts for coding and interpretation. The results were integrated with the quantitative results using a convergence approach in a complementary model. This approach enhanced clarity and objectivity in understanding and explaining the study findings, conclusions, and recommendations derived from the data.

3.9 Ethical Considerations

The study adhered to all the relevant ethical requirements. Ethical approval was obtained from the Kenyatta National Hospital-University of Nairobi (KNH-UoN) Ethics and Research Committee (ERC). Medical record review at the selected facilities was granted an informed consent waiver with reference no. **KNH-UoN/ERC/FORM/IC05**. Informed consent was

obtained from participants for the key informants interviews using a standardized adult participant information and consent form, which provided clear details about the study's purpose, benefits, and voluntary participation. The National Commission of Science Technology and Innovation (NACOSTI) issued a study permit (see Appendix 10). Institutional approvals were also obtained from relevant county governments and study facilities (see Appendix 10-15).

To ensure the confidentiality of study records and data, patient data was anonymized and no actual patient names were used in the analysis outputs, study report and published papers. Unique identifiers were used for both patients and study interviewees to de-identify the data. A crosswalk table with coded spreadsheet links to medical record numbers was used for easy reference and cross-checking of abstracted data by the PI. The key and passwords for accessing the data were stored in a separate password-protected file known only to and administered by the PI, and file access required the investigator's identity authentication. Medical records were reviewed within the premises of the hospital or service provider to minimize the risk of the unauthorized access to patient information. Electronic data was stored in an encrypted database/spreadsheet. De-identified physical notes, filled data review forms, and audio record transcripts were securely kept in a lockable cabinet, with limited access granted only to the PI.

3.10 Dissemination Plan

In line with ethical considerations regarding community participation and the study's benefits to the community, the research results have been disseminated through various channels. A scoping review paper on health system factors associated with prehospital mortality outcomes (Koome et al., 2020) and an original research article on the association between TBI injuries at the prehospital care level and mortality (Koome et al., 2021) were published in international peer-reviewed journals, reaching a wide audience of key policy and programmatic actors.

The dissemination plan also includes presenting the findings at professional conferences and seminars both within and outside Kenya. The target audience for these dissemination efforts includes pre-hospital care system stakeholders, such as government and county EMS representatives, hospital and NGO providers' representatives, and other relevant stakeholders in Kenya who can benefit from the study's valuable findings. Additionally, published research articles and comprehensive final thesis reports (soft copies) will be shared with the management of the institutions where the study was conducted, including KNH, Misericordiae Hospital, Kikuyu Mission Hospital, St. John's Ambulance, the Ministry of Health, and the Research Units of Health Departments in Kiambu and Nairobi Counties.

3.11 Study Limitations

As mentioned in the introduction of this chapter, this thesis comprises two sets of independent but interrelated research outputs: a scoping review and a retrospective study involving data abstraction from medical records and key informant interviews. The limitations of the study are presented separately for each research output.

3.11.1 Scoping Review

The scoping review paper, published in the British Medical Journal (BMJ), focused on African settings or countries (Koome et al., 2020). Initially, a systematic review was planned, but due to quality gaps identified during a preliminary search and team review, a scoping review was conducted instead. The aim was to provide a snapshot of available evidence to guide study priorities and designs based on identified gaps in the existing evidence (Lockwood et al., 2019; Peterson et al., 2017). Many of the included studies did not report statistical association models and findings on the investigated factors limiting the level of evidence derived from the papers.

The search strategy for the scoping review included terms related to health system factors, post-trauma mortality, prehospital care, and study settings, resulting in a large number of screening studies (2350), many of which were not adequately relevant to the study variables. The review focused on prehospital aspects of health systems, such as on-scene transport, access to life-saving interventions, responder/provider types, and referral pathways to definitive care facilities. Although limited scientific evidence was found on the variables of interest, the review was valuable in mapping and identifying research gaps and priorities in prehospital care. The results informed the design and scope of the retrospective case-control study, which aimed to address the gaps identified in the scoping review.

3.11.2 Retrospective Case-Control Study

The retrospective case-control study was limited to three trauma referral hospitals with the capacity to handle complex trauma injuries, specifically, TBIs. These hospitals are located in urban areas, namely Kiambu and Nairobi Counties. Given the limited scientific evidence on the study subject, a nationwide study would have been preferable to cover rural and remote areas which experience greater disparities and inequalities in health care access and potentially different trauma patterns, such as knife stabbing and motorcycle-related falls. These remote and rural areas often have weaker or non-existent EMS and pre-hospital systems. Therefore, the generalization and interpretation of the study results should be cautious when applied to very rural and remote areas in Kenya, as they may differ significantly in terms of patterns, complexity, structures, processes, and capabilities related to prehospital care, potentially resulting in different mortality risks. The study results are most relevant for informing trauma response and out-of-hospital care systems in urban areas.

In Kenya, there are no well-developed trauma registries or data systems to capture comprehensive trauma data, especially at the prehospital care level. Data is fragmented across

different levels of health referral systems and stored in various, formats such as mortality and autopsy reports, physical ambulance record sheets, referral forms, manual registers at A&E departments, and patient medical records. Most of these databases rely on manual data entry and archiving, which can lead to missing or inaccurate records and data. To address these challenges, the retrospective data abstraction, involved sourcing and collating multiple data records available at the prehospital and in-hospital care levels, including referral forms, ambulance sheets, mortality reports, and medical records. Patient files with significant missing data, such as referral notes, were excluded based on the study's eligibility criteria.

To mitigate the limitations of incomplete and fragmented data, a complementary data sourcing technique was employed to collate and triangulate data. However, there were cases of missing data variables. Abstracted data with more than 5% of key data variables missing were excluded. For cases with ≤5% missing data variables, data imputation, a statistical method to address missing data, was used to impute the missing variables in the dataset. Although a prospective longitudinal study could have addressed some of the retrospective limitations associated with retrospective data, the time and resource implications made such a design less feasible.

The study recognizes the inherent limitations of administrative and retrospective data, but these were the only methods available to obtain population level perspectives on TBI outcomes. The study focused solely on the PEC phase of TBI management, which is only a part of the broader trauma care system that includes in-hospital and rehabilitation phases. Incorporating aspects of in-hospital and rehabilitation phases in trauma management would have provided more comprehensive insight into the long-term outcomes of PEC responses, beyond the short-term outcome measure of mortality used in this study. This presents a research gap that could not be fully addressed in the current study. Nevertheless, the findings contribute valuable scholarly insights into trauma care capacity and gaps in the Kenyan PEC system, its potential value in

mitigating TBI mortality burden, and the identification of scientific gaps that can guide further research.

CHAPTER FOUR

FINDINGS

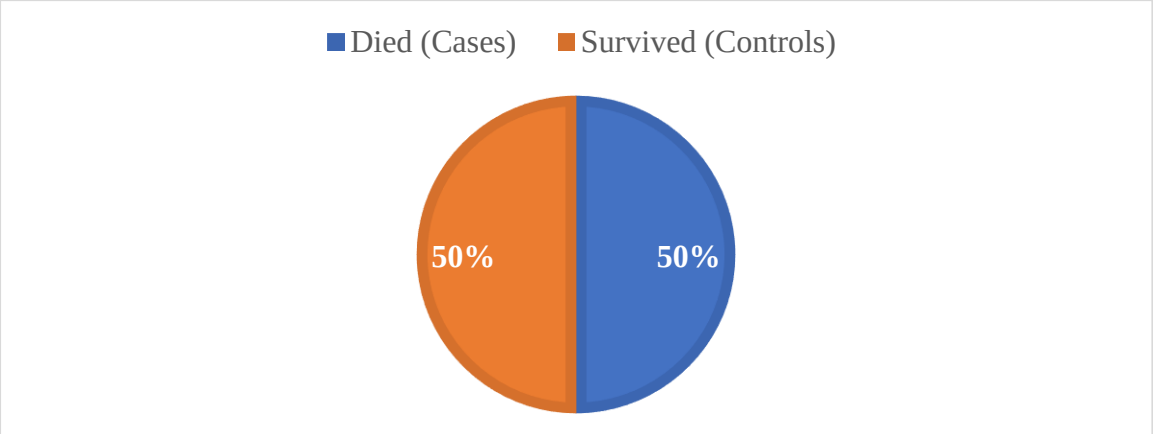
4.1 Introduction

The study findings have been organized and presented in accordance with the study objectives. The first section provides detailed findings on objective 1: Patient characteristics. The second section presents findings on objective 2 regarding TBI patterns, which have been previously published (Koome et al., 2021). The third section presents findings on objective 3: access to PEC. Lastly, the fourth section presents findings on objective 4: Patient transfer pathways. Each section begins with descriptive findings, followed by inferential analysis. Furthermore, qualitative findings from document reviews and key informants have been integrated into the quantitative findings in each section.

4.2 TBI Mortality Outcomes

Cases and controls had equal proportion (50%). Figure 4.1 below describes the proportion of TBI patients who died (cases) and those who survived (controls) one month after admission in a tertiary hospital in this study.

Figure 4.2 Post-Trauma Mortality Outcome



The mortality outcomes of traumatic brain injury (TBI) in relation to patient-related factors, including the Prehospital Emergency Care (PEC), are described in detail in Section 4.3.

4.3 Patient Characteristics and Mortality

4.3.1 Distribution of Mortality Table 4.1

Table 4.1 presents the bivariate descriptive summary findings of the study subjects, categorized by the outcome variable of mortality, using Pearson's chi-square test.

Table 4.1 Descriptive findings of patient characteristics by mortality distribution

Variable		**Mortality Outcome**			**P-value**
		Controls N=158 (%)	**Cases N=158 (%)**	**Total N=316; (%)**	
Age categories	18-29 years	71(45)	64(41)	135(43)	0.876
	30-39 years	46(29)	49(31)	95(30)	
	40-49 years	17(11)	21(13)	38(12)	
	50-59 years	14(9)	12(8)	26(8)	
	60+ years	10(6)	12(8)	22(7)	
Gender	Male	139(88)	129(82)	268(85)	0.158
	Female	19(12)	29(18)	48(15)	
Blood Pressure	Hypertension	63(40)	72(46)	135(43)	0.117
	Elevated	36(23)	24(15)	60(19)	
	Normal	55(55)	66(42)	121(38)	
Trauma Severity	Severe (GCS<9)	54(34)	100(65)	154(49)	0.001***
	Moderate (GCS 9-12)	37(23)	29(18)	66(21)	
	Mild (GCS 13-15)	67(42)	29(18)	96(30)	

Variable		Mortality Outcome			P-value
		Controls N=158 (%)	Cases N=158 (%)	Total N=316; (%)	
Triage Status	Not Urgent	34(22)	47(30)	81(26)	0.229
	Urgent	50(32)	47(30)	97(31)	
	Emergency	74(47)	64(41)	138(44)	
Hypoxemia	Yes	39(25)	60(38)	99(31)	0.001***
	No	119(75)	98(62)	217(69)	
Comorbidity	Yes	57(36)	66(42)	123(39)	0.356
	No	101(64)	92(58)	193(61)	
Alcohol use	Yes	35(22)	52(33)	87(28)	0.044*
	No	123(78)	106(67)	229(72)	
Total Prehospital time	<3 hours	101(64)	79(50)	180(57)	0.027*
	3-6 hours	24(15)	26(16)	50(16)	
	6+ hours	33(21)	53(34)	86(27)	
Transfer Facility	Public	67(42)	100(63)	167(53)	0.001***
	Private	91(58)	58(37)	159(47)	

*p≤0.05; ***≤0.001

In this study, the study subjects primarily consisted of patients below the age of 40, predominantly males, constituting 73% of the total sample. The average age distribution of patients was comparable between the cases and controls, with a p-value of *.876*, indicating no significant difference. Key informants' findings suggest that young individuals are particularly vulnerable to traumatic brain injuries (TBIs). Qualitative data indicates that the majority of TBI injuries are severe, as evidenced by a Glasgow Coma Scale (GCS) score below 9.

According to the information provided by key informants, under-triaging is a prevalent factor contributing to mortality at the primary emergency care (PEC) level, leading to delayed treatment. Notably, the analysis revealed that approximately 30% of severely injured patients who later died were erroneously triaged as non-urgent or non-emergency cases.

Hypoxemia poses a significant challenge at the PEC level, as more than half (57%) of TBI patients were diagnosed with hypoxemia upon arrival at the emergency department. Shockingly, over one-third of hypoxemic patients died before receiving oxygen support, with a p-value of less than .001. A Head of the Accident and Emergency department depicted a bleak picture of the situation:

> *"There is a challenge in oxygen supplementation. Most patients who require it do not receive it until they arrive at a well-equipped facility because it is unavailable. Due to a shortage of oxygen supply, many patients in need of life-saving intervention through intubation do not receive the necessary treatment."*

The distribution of comorbidity was similar among the cases and controls utilized in this study, with *a p-value of 0.358,* indicating no significant difference. Prehospital transport time served as a proxy indicator of the distance to a trauma care facility. Insights from key informants revealed prolonged prehospital times and delays in receiving definitive care due to the absence of efficient rescue command centers with coordinated and reliable communication, as well as ambulance rescue services. Notably, a minority of patients (less than 5%) reached the tertiary care facility within an hour of the accident. Prompt arrival within this timeframe is critical for administering life-saving interventions.

4.3.2 Association between Patient Characteristics and TBI Mortality

A logistic regression model was conducted to assess the impact of patient characteristics on mortality among individuals presenting with TBIs. The results of the model are presented in Table 4.2.

Age did not emerge as a statistically significant predictor of mortality for TBI cases. This finding aligns with the descriptive observation that the study population predominantly consisted of young individuals in their early thirties, with similar mortality rates observed among cases and controls.

Table 4.2 Logit regression model of patient characteristics and mortality

Variable	**Unadjusted Model**		**Adjusted Model**	
	OR (95% CI)	**P-value**	**OR (95% CI)**	**P-value**
Age (ref: 40+ years)		0.725		0.913
18-29 years	0.82(0.48-1.41)	0.476	0.88(0.45-1.72)	0.714
30-39 years	0.97(0.54-1.74)	0.920	0.87(0.42-1.78)	0.695
Female Gender	1.64(0.88-3.08)	0.119	2.65(1.19-5.92)	0.017*
Blood pressure (Ref: Hypertension)		0.119		0.353
Normal	1.04(0.63-1.72)	0.868	1.76(0.41-7.48)	0.445
Elevated	0.55(0.29-1.03)	0.063	0.63(0.29-1.38)	0.249
Trauma Severity (ref: Mild GCS 13-14)		0.001***		0.001***
Severe (GCS<9)	4.28(2.48-7.39)	0.001***	4.00(2.10-7.66)	0.001***
Moderate (GCS 9-12)	1.81(0.94-3.48)	0.075	1.85(0.86-3.99)	0.118
Triage Status (ref: Emergency)		0.236		0.009**
Not Urgent	1.60(0.92-2.78)	0.097	3.01(1.46-6.24)	0.003**

Variable	Unadjusted Model		Adjusted Model	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Urgent	1.09(0.65-1.83)	0.754	1.17(0.61-2.26)	0.634
Presence of Hypoxemia	4.36(2.58-7.36)	0.000	5.95(3.09-11.45)	0.001***
Presence of Comorbidity	1.27(0.81-2.00)	0.299	1.27(0.81-5.26)	0.741
Alcohol Use	1.72(1.05-2.85)	0.033	2.04(1.10-3.78)	0.024*
Public tertiary facility (KNH)	2.34(1.49-3.68)	0.000	2.82(1.51-5.29)	0.001**
Access to prehospital care	0.58(0.37-0.91)	0.018	0.61(0.04-8.66)	0.718

*p≤0.05; **≤0.01; ***≤0.001

Similarly, qualitative findings confirmed that individuals aged 30 years and below exhibited a potential protective effect against mortality compared to individuals aged 40 years and above (odds ratio [OR] = *0.88;* 95% confidence interval [CI]: *0.45-1.72; P = 0.913*). There were no significant variations in age that allowed for substantial statistical discrimination regarding the role of age in mortality among TBI patients. Female patients had a 1.65 times higher risk of mortality compared to male patients (OR = *2.65; 95%CI: 1.19-5.92; P = 0.017*).

Patients sustaining severe TBI (Glasgow Coma Scale [GCS] < 9) were 4.00 times more likely to die compared to those sustaining mild or minor trauma (GCS 13-15) (OR = *4.00; 95%CI:* 2.10-7.66*; P = 0.001*). At the prehospital emergency care (PEC) level, patient under-triaging was reported to pose a significant risk of mortality. For instance, the analysis established that patients triaged as non-urgent were three times more likely to die than those triaged as emergency patients (*OR = 3.01; 95%CI:* 1.46-6.24*; P = 0.003*). According to key informants, under-triaging is a common care gap contributing to avoidable deaths at the prehospital care level.

> *“After evacuation, some patients with perceived minor injuries are discharged home, despite experiencing minor pains or being asymptomatic. Often, minimal or no extensive investigations are conducted based solely on their personal testimony of having no pain or complications after the trauma. Some of these cases result in deaths or other complications that could have been easily prevented” - EMS provider.*

Key informants stated that missed injuries were a result of inadequate diagnostic capacity and skill.

> *"There is an issue with trauma triaging and diagnostic capacity at the prehospital care level, as well as in lower-level facilities. We receive patients with severe post-trauma complications, even days or weeks after discharge, due to missed injuries and other internal organ damage. Many of these cases result in death due to delayed life-saving interventions" - Head of A&E Department.*

Key informants observed that access to oxygen at the PEC level, particularly at the accident scene, poses a significant risk of TBI mortality. The analysis showed that hypoxemic patients had almost six times the risk of dying after the injury compared to non-hypoxic patients (OR = *5.95; 95%CI:* 3.09-11.45*; P = 0.001*). Even when available, primary care facilities have limited skills to perform necessary intubations and provide ventilations for enhanced respiratory support en-route to a definitive care facility.

> *"We receive very few intubated patients. While some lack the skills and experience for intubations, others disregard the importance of performing it " - A&E Nurse.*

Comorbidity was not a statistically significant predictor of mortality, despite comorbid patients showing higher odds of mortality (OR = *1.27; 95%CI:* 0.81-5.26; P = 0.*041*). However, alcohol intoxication significantly increased the odds of dying, being twice that of a non-intoxicated patient.

4.4 Trauma Patterns and TBI Mortality

4.4.1 Descriptive Findings

Three types of trauma patterns were studied: trauma mechanism (road traffic incidents [RTIs] and non-RTI causes), type of injury (blunt and penetrating), and injury day (weekday and weekend). Descriptive summary findings of the trauma patterns and their association with mortality outcomes, derived using Pearson's chi-square test, are presented in Table 4.3.

Table 4.3 The descriptive summary of trauma patterns by mortality distribution

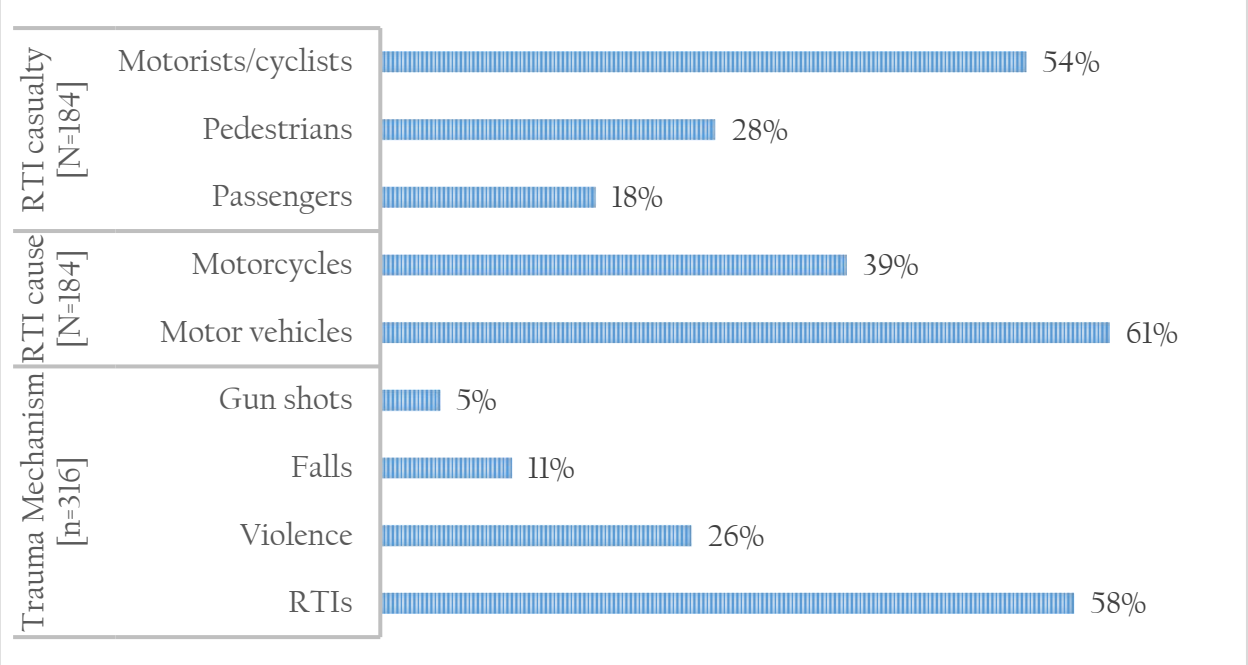
Variable	**TBI Mortality Outcome**		**Total**	**P-value**
	Controls	**Cases**	**(n=316; %)**	
	(N=158; %)	**(N=158; %)**		
Trauma Mechanism				
RTIs	78(49)	106(67)	184(58)	0.001***
Non-RTIs	80(51)	52(33)	132(42)	
Type of Trauma/Injury				
Blunt Injury	103(65)	122(77)	225(71)	0.025*
Penetrating Injury	55(35)	36(23)	91(29)	
Day of Injury				
Weekday	88(56)	81(51)	169(53)	0.499

Variable	TBI Mortality Outcome		Total	P-value
	Controls (N=158; %)	Cases (N=158; %)	(n=316; %)	
Weekend	70(44)	77(49)	147(47)	

*p≤0.05; ***≤0.001

The data extracted from patient files indicates that respiratory tract infections (RTIs) significantly contribute to the escalating mortality burden of traumatic brain injuries (TBIs), as depicted in Figure 4.1 presented below.

Figure 4.2 Main source of Traumatic Brain Injuries



Key informants unanimously agreed that road traffic injuries (RTIs) continue to be a significant contributor to the burden of traumatic brain injuries (TBIs). Interestingly, motorcycles have emerged as a noteworthy source of avoidable burden. A Medical Officer, who was one of the key informants, explained that RTAs (road traffic accidents) are the primary cause of TBIs

observed in their facility. However, over time, injuries related to motorcycles have increased substantially and have even surpassed injuries caused by vehicle accidents. Some medical facilities, have even established separate wards to accommodate the growing number of motorcycle-related injuries.

Analysis revealed higher mortality rate among RTIs survivors compared to non-RTI survivors (67% versus 49%) (*P<.001*). Furthermore, among individuals below the age of 40, gunshot wounds were identified as an increasingly significant risk factor for avoidable TBIs. Key informants linked these injuries to the misuse of firearms by both the general public and law enforcement, such as cases of extrajudicial killings and the use of guns for criminal activities. The Head of the A&E department emphasized the rising incidence of gunshot injuries among young individuals.

Blunt trauma, which is associated with RTIs and falls, was the most commonly reported form of TBI, with a higher prevalence among cases compared to controls (P=.035). Penetrating trauma, on the other hand, was predominantly associated with gunshot wounds and injuries resulting from violence. Through record review and insights from key informants, it was evident that concussions and contusions were the primary internal injuries resulting from TBIs. A Medical Officer captured this observation:

> *"The majority of TBI cases result from blunt trauma, particularly traffic accidents. From my experience, brain contusions and concussions are the most common internal injuries observed in patients who do not survive."*

Additionally, key informants frequently reported skull fractures and scalp wounds as prevalent injuries in TBI cases.

4.4.2 Association between Trauma Patterns and TBI Mortality

To investigate the association between trauma patterns and TBI mortality, a logistic regression analysis was conducted. The results of the logit regression model are presented in Table 4.4.

Table 4.4 Logit regression model of trauma patterns and TBI mortality

Variable	Unadjusted Model		Adjusted Model	
	OR (95% CI)	**P-value**	**AOR (95% CI)**	**P-value**
Road Traffic Injury (RTI)	2.09(1.33-3.30)	0.002**	2.90(1.65-5.11)	0.001***
Blunt Trauma	1.22(1.03-1.44)	0.019*	1.23(1.01-1.50)	0.044*
Weekday Trauma	1.20(0.77-1.86)	0.430	0.95(0.56-1.63)	0.863
Age Categories (ref: 40+ years)		0.725		0.712
18-29 years	0.82(0.48-1.41)	0.476	0.91(0.47-1.75)	0.768
30-39 years	0.97(0.54-1.74)	0.920	1.18(0.58-2.40)	0.645
Female Gender	1.64(0.88-3.08)	0.119	2.62(1.21-5.70)	0.015*
Trauma Severity (ref: Mild GCS<13-15)		0.001***		0.001***
Severe (GCS<9)	4.28(2.48-7.39)	0.001***	3.51(1.88-6.55)	0.001***
Moderate (GCS 9-12)	1.81(0.94-3.48)	0.075	1.66(0.78-3.54)	0.192
Presence of Hypoxemia	4.36(2.58-7.36)	0.001***	4.78(2.61-8.77)	0.001***
Presence of Comorbidity	1.27(0.81-2.00)	0.299	1.78(1.00-3.19)	0.050*
Alcohol Use	1.72(1.05-2.85)	0.033*	2.77(1.48-5.16)	0.001***
Total Prehospital time (ref: 6+ hours)		0.026*		0.715
<3 hours	0.49(0.29-0.82)	0.007**	0.45(0.02-13.09)	0.641
3-6 hours	0.67(0.33-1.36)	0.274	0.73(0.31-1.74)	0.475
Transfer to a public facility	2.34(1.49-3.68)	0.001***	2.01(1.10-3.66)	0.023*

*p≤0.05; **≤0.01; ***≤0.001

The type of trauma mechanism, specifically road traffic injuries (RTIs), and the type of injury, specifically blunt trauma, were identified as significant predictors of traumatic brain injury (TBI) mortality. Patients who experienced RTIs had a 2.9-fold increased risk of mortality following the injury compared to non-RTI patients (*odds ratio [OR] = 2.90; 95% confidence interval [CI]:* 11.65-5.11*; P < .001*). Moreover, sustaining blunt trauma was associated with a 1.23-fold higher risk of TBI mortality compared to sustaining penetrating trauma (OR = 1.23; *95% CI:* 1.01-1.50*; P = .044*).

Interestingly, the day of injury (weekend or weekday) did not serve as a predictor of TBI mortality *(P = .863*). According to key informants, there were no substantial variations in access to life-saving interventions at the pre-hospital emergency care (PEC) level and the quality of critical care upon admission to definitive care facilities during either weekends or weekdays. One of the interviewees stated:

> *"There is no observable difference in the quality of critical care provided during weekends and weekdays. Facilities have well-established schedules for on-duty and on-call staff, as well as specialists in case of emergencies" - Head of the Accident and Emergency Department.*

4.5 Access to Pre-Hospital Care

4.5.1 Descriptive Findings

Descriptive findings regarding access to pre-hospital care, derived using Pearson's chi-square test, are summarized in Table 4.5.

Table 4.5 Descriptive summary of access to prehospital care by mortality distribution

Variable	TBI Mortality Outcome		Total	P-value
	Controls	Cases	(n=316; %)	
	(N=158; %)	(N=158; %)		
Access to pre-hospital care				
Yes	59(37%)	80(51%)	139(44%)	0.023*
No	99(63%)	78(49%)	177(56%)	
Type of Transport Mode				
Ambulance transport	58(37%)	75(47%)	133(42%)	0.068
Non-Ambulance Transport	100(63%)	83(53%)	183(58%)	
Type of prehospital care Provider				
Paramedic	29(18%)	29(18%)	58(18%)	0.020*
Nurse	30(19%)	51(32%)	81(26%)	
Lay responder	99(63%)	78(49%)	177(56%)	

*p≤0.05

The distribution of mortality among patients who accessed prehospital care was significantly lower compared to those who did not access it (*P=0.023*). More than half of the patients (56%) had no access to prehospital care. One of the key informants, a policy actor, confirmed a high demand but limited supply of access to and utilization of prehospital care/life-saving interventions.

> *"The biggest challenge is the lack of effective Emergency Medical Services (EMS) for acute trauma conditions in out-of-hospital care settings, despite the significant demand."*

A paramedic working at the Primary Emergency Care (PEC) level highlighted the gap between supply and demand:

> *"A Member of County Assembly [MCA] started distributing emergency contacts to the community. Over a short period, out-of-hospital rescue distress calls increased beyond our ability to respond with the few county or facility-based ambulances available, which are not even sufficient for inter-facility referrals. As a result, the distribution of the contacts was suddenly halted."*

The findings from the key informants revealed low population-level awareness of emergency distress service responses and contacts, including those provided by private actors such as the Red Cross (E-Plus) Ambulance and St. John Ambulance within the counties. This lack of awareness was linked to low demand, limited access, and underutilization of emergency evacuation services at the PEC level. Without an efficient communication system, the identification, triaging, and evacuation of patients remains a challenge. "

> *Most populations are unaware of reliable emergency care services and distress call contacts." - Medical Officer*

Analysis indicated that advanced life support interventions required for critically ill patients, such as cardiac monitoring, stabilization, the use of anticoagulants, defibrillation resuscitation, and intubations, were not readily available or easily accessible at the PEC level. Patient monitoring and recording of vital signs during transport to referral hospitals for further management were rarely performed. These actions were primarily carried out by private ambulatory service providers, mainly staffed by trained personnel or paramedics.

> *"Patients are usually transferred to the nearest facilities before referral to tertiary hospitals for specialized care. Despite making significant*

improvements, many primary care facilities, including county and sub-county hospitals, lack most of the basic resources, skills, and equipment to provide advanced life support interventions and specialized trauma care, leading to unnecessary referrals and subsequently, avoidable deaths." - County Health Executive.

Advanced life support (ALS) interventions were mainly provided or available at emergency departments where the required equipment and skills are present, primarily in tertiary hospitals. Most primary hospitals lack the necessary skills and competence to provide ALS interventions.

Similarly, as noted by the key informant, private or non-ambulatory modes of transport, such as personal vehicles and pulling carts without basic lifesaving equipment, are the main forms of emergency evacuation at the PEC level. The access or use of ambulance transport directly from the injury scene is very limited or rare.

"Most of the patients arrive by private vehicles, cabs, or on foot from injury scenes. There are only a few cases of ambulatory transport directly from the injury scene." - Patient Referral Coordinator.

However, upon arrival or transfer to primary care facilities using non-ambulatory transport, most patients are further transferred to tertiary hospitals for advanced care management by public ambulances.

According to key informants, trained EMS providers are not available at the PEC level. On-scene evacuation is mostly left to well-wishers, which increases the risk of delays in care, avoidable deaths, and related health complications due to skill and capacity breaches. Patients rescued by lay responders were significantly more common in the control group compared to

the cases (63% vs. 49%) (*P=0.020*). The distribution of mortality among patients rescued by lay responders was similar in both cases and controls (*P=0.068*).

Similar to the key informant findings, the majority of the patients were rescued and assisted by untrained bystanders, also known as "lay responder care." The key informants' findings indicated an acute shortage of trained EMS providers at the PEC level. Most publicly owned ambulances do not have trained EMS providers and are dispatched with only an intern and a driver who lack basic first aid skills. "Most of the public ambulances do not have trained EMS providers. The ambulances are operated by drivers without basic first aid skills.

> *"Many of the private ambulances have trained staff but not the case in public ambulances." - NGO EMS provider"*

Due to deficits in first aid or critical care skills, the rescue efforts by lay or untrained responders were noted to increase the risk of mortality due to mishandling of patients, especially those with serious and delicate head injuries such as internal bleeding, central nervous system (CNS) trauma, and brain damage.

> *"Mishandling of trauma patients during rescue operations, such as in vehicle wrecks and en route to the hospital, is responsible for many avoidable deaths." - Head of Emergency Department*

According to key informants, the lack of community-based emergency response (CBER) systems is the main system gap contributing to the risk of patients being mishandled by untrained lay responders. There is low community or population-level EMS awareness, training, and capacity building.

4.5.2 Association between Access to Prehospital Care and Traumatic Brain Injury (TBI) Mortality

A logistic regression model was used to examine the association between access to prehospital life-saving interventions and mortality. The results of the model are presented in Table 4.6.

Table 4.6 Logit model of access to life-saving intervention and mortality

Variable	Unadjusted Model		Adjusted Model	
	OR (95% CI)	P-value	AOR (95% CI)	P-value
Access to PEC	0.58(0.37-0.91)	0.018*	0.52(0.03-9.32)	0.659
Ambulance Transport	0.64(0.41-1.01)	0.053	0.35(0.06-2.06)	0.244
Type of EMS responder (ref: Lay responder)		0.020*		0.734
Paramedic	0.79(0.43-1.43)	0.432	0.30(0.01-9.68)	0.496
Facility-based provider rescue	0.46(0.27-0.80)	0.005**	0.60(0.03-13.14)	0.747
Age Categories (ref: 40+ years)		0.725		0.843
18-29 years	0.82(0.48-1.41)	0.476	0.83(0.44-1.56)	0.566
30-39 years	0.97(0.54-1.74)	0.920	0.92(0.47-1.82)	0.812
Female Gender	1.64(0.88-3.08)	0.119	2.41(1.14-5.09)	0.021*
Trauma Severity (ref: Mild GCS<13-15)		0.001***		0.001***
Severe (GCS<9)	4.28(2.48-7.39)	0.001***	3.77(2.04-6.94)	0.001***
Moderate (GCS 9-12)	1.81(0.94-3.48)	0.075	1.63(0.79-3.35)	0.187
Presence of Hypoxemia	4.36(2.58-7.36)	0.001***	4.40(2.44-7.91)	0.001***
Presence of Comorbidity	1.27(0.81-2.00)	0.299	1.59(0.92-2.77)	0.098
Alcohol Use	1.72(1.05-2.85)	0.033*	2.25(1.25-4.06)	0.007**
Total Prehospital time (ref: 6+ hours)		0.026*		0.817

Variable	Unadjusted Model		Adjusted Model	
	OR (95% CI)	P-value	AOR (95% CI)	P-value
<3 hours	0.49(0.29-0.82)	0.007**	0.44(0.02-8.13)	0.583
3-6 hours	0.67(0.33-1.36)	0.274	1.14(0.19-6.72)	0.882
Public transfer facility	2.34(1.49-3.68)	0.001***	1.92(1.09-3.40)	0.024*
Direct patient transfer	2.03(1.21-3.42)	0.007**	1.47(0.08-27.61)	0.798

*p≤0.05; **≤0.01; ***≤0.001

Access to prehospital care does not predict traumatic brain injury (TBI) mortality at the prehospital emergency care (PEC) level (*OR=0.52; 95%CI:* 0.03-9.32*; P=.659*). According to EMS experts, despite a high demand, the majority of the population does not have access to quality life-saving prehospital care. Qualitative findings confirm that existing PEC systems are the weakest link in addressing the increasing burden of TBI in the country. These systems are dysfunctional and ineffective in reducing avoidable mortalities.

Several gaps were said contribute to the limited access to PEC, including weak emergency medical services (EMS), absence of relevant policy and leadership structures, insufficient basic equipment such as well-equipped ambulances and ambulance dispatch systems, inadequate staff, and primary facility capacity to provide recommended life-saving interventions promptly and efficiently. For example, desk reviews and key informants indicate that the government has not prioritized EMS at the PEC level, despite it being a constitutional right and a significant contributor to the non-communicable disease burden in the country.

According to the head of an NGO rescue services, EMS has not been and is currently not at the forefront of public trauma burden interventional priorities in Kenya. The focus has been largely on communicable diseases such as HIV/AIDS, Malaria, and TB, despite trauma burden

becoming a leading cause of mortality in Kenya and other low- and middle-income countries. Similarly, a critical care nurse noted a lack of right skills because of limited investment by the government in EMS.

Key informants link the lack of appropriate legal and policy frameworks for EMS to the existing weaknesses in institutional leadership, funding, and other systemic reforms needed to establish a functional, coordinated, and responsive PEC system. A representative of a national policy actor observed:

> *"We don't have a formal EMS act or policy in the country to give life to the constitutional right to quality PEC; we have a draft that has yet to be adopted in parliament since 1999. We hope to have the policy adopted to streamline and regulate the sector."*

The implementation of PEC as part of constitutional rights remains a 'mere policy statement" on paper due to the lack of relevant legal, policy, and institutional frameworks to operationalize the intended services.

Analysis established that ambulance transport does not significantly impact TBI mortality outcomes at the prehospital care level (OR=0.35; 95%CI: 0.06-2.06; P=.244). Key informants affirmed the high demand but limited supply of well-equipped and staffed ambulatory care at the PEC level for TBI patients. The county ambulance coordinator said:

> *"There are shortages of ambulances in the entire county. One ambulance can be earmarked for inter-facility referrals for an entire catchment area with limited history of use at the PEC level."*

The few well-equipped and staffed ambulances, primarily privately-owned, are accessible to only a small portion of the population, mainly the elites. A critical care nurse explained:

> *"Many private ambulances are well-equipped and staffed to provide quality advanced life support interventions. Patients with timely access to these ambulances may have a lower risk of death at the PEC level. However, they are mainly used by well-off people who can afford the service fees or have insurance coverage."*

Some key informants describe the ill-equipped public ambulances as "public taxis" or "transport vehicles" registered as duty-free vehicles rather than evacuation vehicles. These ambulances are said to lack basic minimum equipment or facilities such as oxygen supplies, first aid kits, and defibrillators to support quality life-saving interventions for critically injured

4.6 Type of Patient Transfer Pathways

4.6.1 Descriptive Findings

The study investigated two primary types of patient transfer pathways: direct transfer and indirect transfer. Direct transfer involves the transfer of patients directly from the injury scene to a tertiary facility. On the other hand, indirect transfer entails the transfer of patients from injury sites to a tertiary facility through primary health facilities. The study also analyzed the influence of the transfer facility type on mortality rates within the referral/patient transfer pathway. A descriptive analysis of the types of patient transfer pathways and the types of tertiary transfer facilities, along with their association with mortality, was conducted using Pearson's chi-square test. The findings from this analysis are presented in Table 4.7.

Table 4.7 Descriptive Summary of the Type of Patient Transfer Pathway by Mortality Distribution

Variable	Mortality Outcome		Total	P-value
	Controls (N=158; %)	Cases (N=158; %)	(n=316; %)	
Patient Transfer Pathway				
Indirect Transfer	30(19%)	51(32%)	81(26%)	0.010**
Direct transfer	128(81%)	107(68%)	235(74%)	
Tertiary Transfer Facility Disposition				
Public	67(42%)	100(63%)	167(53%)	0.001***
Private	91(58%)	58(37%)	149(47%)	

p≤0.05; *≤0.001

The most commonly utilized pathway for transferring patients from the injury scene to tertiary trauma care hospitals is through direct transfer. Key informants have identified the distance to the nearest facility, rather than the capacity of pre-hospital emergency care (PEC), as the primary determinant for indirect patient transfer. Indirect transfers occur mainly through primary health facilities, where patients either walk in or are rescued by well-wishers without access to transportation.

> *"When patients at the injury scene lack means of transportation to a suitable hospital, they are taken to the nearest available facility regardless of the severity of their injury or the capability of the facility to provide necessary care. Unfortunately, some of these patients die at the facility, during transportation,*

*or shortly after arrival or admission to the hospital due to delayed c*are." - *explained a Medical Officer.*

Indirect transfer patients, due to avoidable delays in receiving definitive care before reaching the hospital, exhibited a significantly higher mortality rate compared to direct transfer patients (P = 0.*010*). Key informants confirmed the existence of gaps in inter-facility and provider referral communication infrastructure and system functionality. Primary facilities frequently encountered high rejection rates for critical referral requests and experienced delays in receiving approval from public tertiary hospitals, which contributed significantly to preventable deaths within the referral systems.

> *"There is a lack of seamless coordination and communication systems between primary and tertiary hospitals for the prompt referral of critical cases. An objective system to verify and validate the urgency of referral requests is absent. Consequently, many patients die or deteriorate while awaiting referral approval, sometimes tied to bed availability, in tertiary hospitals like KNH." - EMS Critical Care Nurse.*

Most patients are transferred to public hospitals due to the lower cost of emergency care compared to private hospitals. The perceived quality of care provided by these public health facilities is a secondary factor. A patient referral coordinator in a tertiary hospital stated:

> *"The primary reason for patients being transferred to public facilities is their inability to afford the relatively higher fees charged by private care providers."*

Compared to private tertiary facilities, there were significantly higher mortality rates among patients transferred to public tertiary facilities (P < 0.*001*).

4.6.2 Association between Type of Patient Transfer Pathway and TBI Mortality

To determine the association between the type of patient transfer pathway, the type of tertiary transfer facility, and mortality, a logit model was performed. The results of the logit model are presented in Table 4.8.

Table 4.8 Logit regression model of type of referral pathway and mortality

Variable	**Unadjusted Model**		**Adjusted Model**	
	OR (95% CI)	**P-value**	**AOR (95% CI)**	**P-value**
In-direct Transfer/Referral	2.03(1.21-3.42)	0.007**	1.49(0.27-8.20)	0.646
Public Transfer Facility	2.34(1.49-3.68)	0.001***	1.90(1.08-3.36)	0.026*
Age Categories (ref: 40+ years)		0.725		0.843
18-29 years	0.82(0.48-1.41)	0.476	0.83(0.44-1.56)	0.566
30-39 years	0.97(0.54-1.74)	0.920	0.92(0.47-1.81)	0.811
Female Gender	1.64(0.88-3.08)	0.119	2.44(1.15-5.14)	0.020*
Trauma Severity (ref: Mild GCS<13-15)		0.001***		0.001***
Severe (GCS<9)	4.28(2.48-7.39)	0.001***	3.71(2.02-6.82)	0.001***
Moderate (GCS 9-12)	1.81(0.94-3.48)	0.075	1.60(0.78-3.29)	0.201
Presence of Hypoxemia	4.36(2.58-7.36)	0.001***	4.45(2.48-8.00)	0.001***
Presence of Comorbidity	1.27(0.81-2.00)	0.299	1.59(0.91-2.76)	0.101
Alcohol Use	1.72(1.05-2.85)	0.033*	2.27(1.26-4.08)	0.006**
Total prehospital time (ref: 6+ hours)		0.026*		0.991
<3 hours	0.49(0.29-0.82)	0.007**	0.96(0.18-5.14)	0.964
3-6 hours	0.67(0.33-1.36)	0.274	1.01(0.18-5.81)	0.987

*p≤0.05; **≤0.01; ***≤0.001

The patient transfer pathway type does not serve as a predictor of Traumatic Brain Injury (TBI) mortality at the Prehospital Emergency Care (PEC) level. However, it was observed that the indirect transfer pathway increased the risk of mortality by 1.49 times compared to the direct transfer pathway (*OR=1.49; 95%CI:* 0.27-8.20*; P=.659*).

Additionally, in conjunction with existing capacity gaps, key informants expressed concerns about the ineffectiveness of the current referral care systems, which leads to avoidable evacuation delays. The findings from these key informants suggest that the leadership and governance of the PEC referral system are weak, fragmented, disjointed, and disorganized. There is a lack of institutional capacity to drive and lead reforms, including the implementation of a referral system at the PEC level. An Emergency Medical Services (EMS) provider observed:

> *"In the country, KCEMT is the only institutional body advocating and representing the highly fragmented PEC stakeholders at the national level, but it is perceivably incapacitated to effectively undertake its policy, leadership, and advocacy mandates." - NGO EMS provider.*

The desk review and key informants' findings revealed an increasing conflict of interest among stakeholders, which is linked to ineffective coordination mechanisms and sector (PEC) legislation. A head of County Ambulance Services explained:

> *"There are feelings of mistrust and business competition among private EMS providers, hampering central coordination and collaboration. The main problem lies in the lack of harmonized regulation and unified leadership in this practice."*

The lack of mortality benefits from the existing referral pathways can also be attributed to non-adherence to referral guidelines, including ambulance dispatch, minimum patient care, care documentation, inter-facility coordination, and post-referral feedback for improvement. A patient referral coordinator highlighted:

> *"There is a referral structure in the country, but it is not effective. Referral guidelines are not adhered to." - Patient Referral Coordinator.*

In addition, poor capture, documentation, and post-referral feedback of referral care data were identified as significant barriers to ensuring continuity and improvement of evidence-driven life-saving interventions as part of the quality PEC standard. An Emergency Medicine Care Expert mentioned:

> *"Appropriate patient data is rarely or poorly recorded at the injury scene or during referral, especially in public ambulances. Sometimes, this is intentionally done to avoid medical liability and culpability. This significantly hampers the continuity of quality life-saving interventions at the next level of care."*

Facility checks confirmed the findings of the key informants, indicating that information systems are manual and lack data interoperability coordination, and sharing between PEC levels and referral care facilities.

The logit model demonstrated that the type of tertiary transfer facility independently predicts TBI mortality. Key informants agreed that PEC outcomes for TBI can vary depending on the type of transfer facility due to variation in quality of PEC services in private facilities. Public tertiary hospitals were associated with lower capacity to meet sustained higher care demand,

indifferent staff attitudes, inferior or less-equipped facilities, and weak performance accountability systems. The following quotes from interview capture this finding:

> *"For sure, we rarely have anyone dying in our ambulances except for severe cases. Most deaths occur after we hand over the patient to the facility, mainly due to avoidable delays, quality of care, and incompetence. In particular, public facilities are synonymous with avoidable deaths." - Private EMS provider.*

> *"The type of hospital where a patient is received matters most in deciding where to evacuate patients; it signifies promptness and quality of life-saving care accessible to the patient." - Ambulance coordinator.*

In line with these qualitative findings, transfer to a public tertiary facility carried a 1.90 times higher risk of TBI mortality compared to transfer to a private facility (*OR=1.90; 95%CI:* 1.08-3.36*; P=.026*).

CHAPTER FIVE

DISCUSSIONS

Traumatic brain injuries (TBIs) constitute a substantial global health burden, with an estimated 69 million cases occurring annually worldwide (WHO, 2014). Low- and middle-income countries (LMICs) including Kenya, bear approximately 80% of this burden. These injuries result from various causes such as road accidents, falls, and violence, leading to significant morbidity and mortality. In resource constrained setting like Kenya, weak prehospital emergency care systems, limited resources and lack of awareness further escalate the burden. Therefore, understanding the factors associated with TBI mortality at the prehospital emergency care (PEC) level is crucial as it can pave the way for improved practices in prehospital emergency care.

Scientific evidence plays a vital role in informing cost-effective interventions, develop tailored capacity building programs and establishing locally-responsive PEC systems for TBI management in these resource-constrained settings. By enhancing prehospital emergency care, timely assessment, stabilization, and transportation of TBI patients can be achieved, ultimately improving care outcomes and reducing the burden of disability and death associated with TBIs in developing countries. This study aimed to examine the influence of patient-related characteristics on TBI mortality at the PEC level. Additionally, the association between trauma patterns, access to prehospital emergency care, type of patient referral pathways, and TBI mortality was determined. The findings were compared with other empirical studies to gain insights into policy practices and areas requiring interventions or improvement in the PEC system.

5.1 Patient Characteristics

Patient characteristics can provide valuable insights into the status of patients, even with limited invasive interventions. These characteristics include patient age, gender, trauma severity, comorbidity, state of consciousness, triage category, and blood oxygen concentration, among others.

Contrary to many past studies that have reported higher mortality risks among aging patients in all forms of trauma, the study found that traumatic brain injury (TBI) mortality does not increase with age. This finding is attributed to the study's highly young population, with less than 40 years of age and only 7% aged over 60 years. Similar results from other low- and middle-income countries (LMICs) have also supported this finding, where comorbidity was not identified as a risk factor for trauma mortality (Mollayeva et al., 2017; Möller et al., 2018; Ono et al., 2015; Sanghavi et al., 2015). However, the difference in this study's finding is due to comorbidity being a mortality risk among older individuals (60+ years), who constituted only 7% of the study sample. To gain a comprehensive understanding of the role of age in TBI mortality, it is recommended to analyze a larger population sample with a fair distribution of young and older patients. Therefore, the generalization of this study's findings should be limited to young populations of 50 years and below, who are at the highest risk of TBI globally.

Despite the marginal effect of age on TBI mortality, the study revealed that young persons, particularly males aged 19-44 years, are the main casualties of TBIs, indicating a higher prevalence of TBIs among males. This finding is consistent with other empirical studies (Chalya et al., 2012; Mahama et al., 2018; Möller et al., 2018) that have reported disproportionately higher general trauma mortality rates among young individuals. The heightened injury risks among young people are associated with their risky lifestyle, such as frequent traveling and engagement in high-risk socio-economic activities, including drunk

driving and drinking (Boschini et al., 2016; Mahama et al., 2018). The high burden of TBIs among young populations has negative impacts on socio-economic productivity and the country's development, as it results in the loss of productive human capital or assets.

Patient gender was found to be significantly associated with TBI mortality, with male patients exhibiting a higher burden of TBI prevalence and female patients having the highest risk of TBI mortality. A study conducted in Iran attributed the higher injury risks among males to their increased involvement in potentially injurious activities such as high-speed driving, armed activities, and high-rise building construction, among others (Norouzi et al., 2012). Previous studies have reported mixed findings regarding the role of patient gender in overall TBI mortality (Al-Shaqsi et al., 2014; Dasari et al., 2017; El-Menyar et al., 2014). However, females are shown to be more vulnerable to post-TBI deaths compared to males. The increased risk of TBI mortality among females is linked to a heightened risk of developing somatic and psychiatric comorbidity, as well as associated functional decline after injury (Dasari et al., 2017; El-Menyar et al., 2014; Rubenson Wahlin, Ponzer, Lövbrand, et al., 2016; WHO, 2016). Therefore, gender-targeted initiatives aimed at mitigating TBI mortality risks among females and TBI morbidity risks among males are warranted.

Trauma severity has been identified as a risk factor for TBI mortality, with higher trauma severity (GCS score of <9) associated with approximately four times the risk of TBI mortality. This finding is consistent with other studies that have reported higher mortality rates among severely injured patients (Chalya et al., 2012; Eefect et al., 2016; Pakkanen et al., 2015; Shah et al., 2013; Strnad et al., 2015). The risk of health deterioration and non-reversible pharmacological decline is even greater in the absence of prompt life-saving interventions, such as oxygen support at the pre-hospital emergency care (PEC) level and delayed definitive care, including ICU interventions.

These findings emphasize the importance of using the Glasgow Coma Scale (GCS) to assess and classify injury severity at the PEC level and upon admission to emergency departments. This study confirms the use of GCS as a fundamental triaging tool capable of establishing clinical urgency prioritization among TBI patients. The lack of reliable diagnostic tools and staff skills can hinder the prioritization of life-saving interventions, thereby increasing mortality risks, particularly in cases of pre-hospital delays in transporting critical patients to definitive care. Since GCS is a time-sensitive indicator, regular re-evaluation and monitoring at the scene and during transportation to the hospital are recommended. This is particularly crucial for patients who initially present with missed internal injuries during triaging, as their GCS can deteriorate rapidly. Commonly missed injuries among severely injured patients include internal brain hemorrhage and organ damage.

The study found that under-triaging increases the risk of traumatic brain injury (TBI) mortality. This finding is consistent with multiple studies that have identified under-triaging in general trauma cases as a risk factor for mortality outcomes (Lampi et al., 2018; McCoy et al., 2013; Oliver et al., 2017b; Singh et al., 2011). In our study, we observed that almost a third of the TBI mortality burden could be attributed to cases of under-triaging or incorrect triaging of patients. Cases of missed internal injuries, primarily associated with under-triaging at the prehospital care level, were confirmed upon admission to the tertiary trauma care hospital. In these cases, the initial triage level was revised to indicate urgency or emergency. In the context of TBI, under-triaging, which is commonly reported in non-invasive internal injuries, continues to contribute significantly to the mortality burden.

Previous studies have reported that under-triaged patients, often categorized as 'non-urgent' with unknown internal injuries, are frequently discharged home after the injury, leading to avoidable complications during their time at home (Lampi et al., 2018; McCoy et al., 2013;

Oliver et al., 2017b; Singh et al., 2011). Many of these cases resulted in deaths upon readmission to hospitals. For example, some patients who were triaged as having minor injuries and were discharged home without admission or advanced treatment and care were subsequently readmitted as urgent or very urgent cases after a period ranging from one to two weeks.

According to Lampi's study, an injured patient with normal physiological parameters may develop complications later due to invisible injuries (Lampi, 2017). This suggests that patient triaging is a dynamic process that requires regular review and monitoring of patients at the scene, during transportation, and upon emergency admission. These findings align with global evidence that under-triaging is associated with delays in definitive care and an increase in avoidable mortality burden (Coyle and Harrison, 2015; Drennan and Verbeek, 2015).

Gaps in staff skills, limited diagnostic capacity at the PEC level, and lack of regular patient monitoring en-route to the hospital are some of the risk factors for under-triaging. This finding mirrors other studies done in LMICs, which show that most evacuations from injury scenes are provided by lay responders who don't have basic triaging skills (Heidari et al., 2019; Jayaraman et al., 2009; Kuzma et al., 2015a). The situation is worsened by the lack of well-resourced and coordinated EMS communication or command center to support quality patient triaging remotely and on-scene in case of distress calls by lay responders. This means that under-triaging is a significant cause of delays in receiving timely life-saving interventions, attributable to 'surprise deaths,' also known as 'unexpected' or arguably, 'preventable' deaths. The study affirms that accurate patient triaging at the PEC level is an important quality EMS care process capable of mitigating avoidable TBI burden. The triage category remains an important life-saving care protocol in defining optimal pre-hospital care pathways and clinical priority for patients.

In this study, unconscious patients had a higher TBI mortality risk. Similarly, a Ghanaian study reported higher general trauma mortality odds among unconscious trauma patients compared to conscious patients (Mahama et al., 2018). Patient consciousness conferred substantial mortality protection after TBI. Unlike unconscious patients, conscious patients have the privilege of articulating and pointing out easily missed injuries and trauma signs while working with responders and health teams during evacuation and care processes. They form part of the critical life-saving interventions and care decision-making process at the PEC level, which can significantly improve care outcomes.

According to a study by Brian et al., conscious patients can benefit from adjustment or augmentation of their current therapy based on reported health status and expressed or perceived feelings (Blyth and Bazarian, 2010). Conscious patients have the advantage of promptly seeking well-equipped private ambulances from nearby facilities, including air ambulances, while exercising discretion for advanced definitive trauma care treatment in expensive and well-equipped private hospitals, which can positively influence life-saving care outcomes. In the context of a weak PEC system devoid of relevant diagnostic and life-saving capacity, the findings show that unconscious patients are at a higher risk of potentially avertable TBI mortality.

The study failed to confirm patients' blood pressure as a risk factor for TBI mortality. However, analysis of odds statistics suggested a likelihood of higher mortality risks for patients with blood pressure issues, especially the elderly. This finding differs from two other studies which reported a significant association between higher blood pressure at admission and all forms of trauma mortality (Chalya et al., 2012; Strnad et al., 2015). The difference in findings can be partly explained by several reasons: (i) our study population mainly consisted of young patients aged less than 40 years; (ii) our study categorized blood pressure into three categories (normal,

moderate, and high [hypertension]), while the reviewed studies categorized them into two (high and low); and (iii) our study focused only on TBI patients, whereas the other two studies included various forms of trauma injuries such as crush injuries, spinal cord injuries, amputations, facial injuries, acoustic injuries, and spinal injuries. While these reasons may explain the differences to some extent, further studies comprising diverse yet representative populations of TBI patients across different age groups are recommended.

In this study, hypoxemia, defined as a blood oxygen concentration (SpO2) of less than 90%, was found to increase the risk of TBI mortality by over five times compared to that of a normal patient. Empirical evidence indicates that general traumatic injuries, particularly internal organ injuries, can compromise blood oxygen supply and concentration, leading to a hypoxic condition and avoidable deaths (Spaite et al., 2017). Consistent with this study, several other studies have shown that a single episode of hypotension can dramatically increase mortality risks (Fevang et al., 2017; Jousi et al., 2010; McMullan et al., 2013). Current protocols for general trauma care recommend prioritizing oxygen support for hypoxemic patients at the prehospital emergency care (PEC) level as an essential life-saving intervention (Eskesen et al., 2018; McMullan et al., 2013; Sittichanbuncha et al., 2015). Early initiation of oxygen supplementation among hypotensive patients has been shown to effectively restore normal vital body functioning and prevent irreversible damage to body cells and the brain (Sittichanbuncha et al., 2015).

Limited access to oxygen supplementation is a challenge in PEC settings. Consistent with this finding, a study by Strnad et al. concluded that in low- and middle-income countries (LMICs), only a few hypoxemic patients receive oxygen support at the injury scene and during transport to the hospital (Strnad et al., 2015). During on-scene rescue and the evacuation of critical TBI patients, there are significant gaps in the capacity to provide oxygen support to patients

experiencing respiratory distress (hypoxemia). Indicated intubations necessary to maintain the airway and oxygen saturations are rarely performed at the PEC level, especially at the injury scene and during transport to the hospital, due to both limited access and insufficient skills for proper patient intubation. Even in the emergency department of primary care facilities, there is either a limited oxygen supply or a lack of skills for indicated intubations for critical patients. Through desk review analysis, no comparative study examining the relationship between hypoxemia and TBI mortality at the PEC level was found. Instead, the main focus of existing studies is on general trauma rather than specific TBI cases.

5.2 Trauma Patterns

Road Traffic Injuries (RTIs), particularly blunt trauma, significantly contribute to the burden of Traumatic Brain Injuries (TBIs) (Möller et al., 2018). The type of trauma mechanism, such as RTIs, and the type of injury, specifically blunt trauma, are risk factors for TBI mortality. However, the day of the injury, whether it is a weekend or weekday, does not affect TBI mortality.

Road Traffic Injuries, including vehicle crashes, motor vehicle crashes, and pedestrian accidents, among others, are a major public health issue and a significant contributor to the high burden of TBIs in the country. This finding is consistent with other empirical evidence (Balikuddembe et al., 2017; Boschini et al., 2016; Chalya et al., 2012; Möller et al., 2018) that confirms the substantial impact of RTIs. These studies indicate that RTIs account for almost 60% of the TBI burden. Suryanto et al. (2017) found that RTIs contribute to over 50% of the general trauma burden in Low- and Middle-Income Countries (LMICs). Pedestrians, unrestrained passengers, and reckless motorists are particularly vulnerable to RTIs (Tansley et al., 2015). Factors such as non-compliance with road traffic rules among road users (Suryanto

et al., 2017), poor road designs, and public ignorance of safety rules contribute to the persistent high incidence of RTIs.

Motorcycle-related RTIs have gradually become a significant contributor to the overall trauma burden, including TBIs, in several LMICs, including Ghana, India, Kenya, and Uganda (Balikuddembe et al., 2017; Boschini et al., 2016; Chalya et al., 2012; Suryanto et al., 2017). In Kenya, injuries related to motorcycles have surpassed those related to vehicles. The increasing burden of motorcycle-related trauma overwhelms the limited capacity of the Emergency Medical Services (EMS) and the general healthcare system to effectively respond to critical trauma cases, both at the Prehospital Emergency Care (PEC) level and in trauma care facilities. The lack of fully functional and efficient EMS responses at the PEC level exposes TBI patients to higher risks of preventable mortality due to delays in prehospital life-saving interventions.

Non-road traffic incidents, such as public violence (e.g., robbery), gun misuse, domestic violence, and falls, also contribute significantly to TBI mortality. Over time, Kenya has experienced an increase in public violence, marital violence, gun-related incidents, and conflicts, which have emerged as drivers of TBI morbidity. The access, possession (both legal and illegal), and misuse of small arms and light weapons have escalated crime rates, leading to severe head injuries. Due to inadequate EMS systems, many victims of these incidents are unlikely to receive life-saving interventions or first aid care outside of hospital settings. The lack of simple life-saving interventions, such as bleeding control, resuscitation, airway support, and prompt transportation to healthcare facilities for advanced critical care, remains a pressing concern for strengthening the health system. In Kenya, as well as in other LMICs, road safety and community awareness campaigns have not succeeded in reducing the overall trauma burden without effective and resilient EMS responses at the PEC level.

Desk reviews did not find similar empirical studies examining the association between trauma mechanisms and TBI mortality at the pre-hospital emergency care (PEC) level. The few available studies (Balikuddembe et al., 2017; Boschini et al., 2016; Eefect et al., 2016) examined only one trauma mechanism, mainly road traffic injuries (RTIs), which encompassed all forms of trauma different from this study, which focused exclusively on TBIs. Thus, this finding holds significant scholarly value at the PEC level.

The study found that patients sustaining blunt trauma had higher mortality risks compared to those with penetrating injuries such as gunshots and sharp cuts. These findings differ from two previous studies (Kim et al., 2017; Möller et al., 2018), which reported higher mortality among patients with severe penetrating trauma compared to blunt trauma. The difference in findings can be attributed to variations in the composition of the study samples. While this study exclusively focused on TBIs, the two studies included general trauma samples, which encompassed non-TBI traumas such as heart attacks, strokes, meningitis, amputations, and others.

This finding is consistent with other studies that have shown road traffic injuries and falls to be the most prevalent forms of blunt trauma, while penetrating trauma is most prevalent in gunshots, stabs, and other invasive traumas (Kim et al., 2017; Strnad et al., 2015). In this study, the increased risks associated with blunt trauma are attributable to the high prevalence of concussions and contusions, which are commonly reported in head injuries. These findings are further supported by a Kenyan study by Shisoka, which found that head injuries are associated with approximately a 1.5 times increase in the odds of death compared to non-head injuries (Shisoka, 2013). The analysis revealed that both blunt and penetrating trauma can result in serious internal organ injuries and bleeding, which can be easily missed during patient assessment or triaging at the PEC level due to skill and diagnostic equipment capacity gaps.

Serious internal injuries require advanced life-saving interventions, including the administration of relevant medications, coagulants, minor surgeries, among others. These capacities are rarely available in primary facilities that are expected to be well linked with PEC to provide a continuum of care.

The study findings indicate no significant association between the day of injury (weekday and weekend) and TBI mortality. This means that the day of injury does not confer any significant mortality advantage to TBI patients. In this study, weekends were defined as starting from Friday noon to Sunday midnight. The reviews did not find similar studies examining the relationship between the day of injury and TBI mortality to compare the study findings. Existing evidence primarily describes general trauma prevalence, focusing on occurrences during the day or night, unlike this study, which specifically examined the actual day of injury without categorization into nighttime and daytime. For instance, Chalya et al. reported higher injury rates during the daytime compared to nighttime (Chalya et al., 2012).

In another study, Möller et al. (2018) found higher trauma admissions during weekends, especially between midnight and six in the morning, compared to weekdays. The analytical design of these studies differs from the scope of this study; therefore, they cannot be used for comparative purposes. For instance, the admission day at the facility may differ from the injury day based on the timeliness of on-scene evacuation (transport delays) and the promptness of the referral system. Patients injured overnight may be rescued many hours later, potentially the next day, while patients retained longer in the emergency department at primary care facilities may be admitted to a tertiary hospital a day or more after the injury. This means that statistical findings for the injury day and admission day may not be comparable.

Due to a lack of sufficient empirical evidence to compare the findings, further empirical studies examining the role of the injury day on traumatic brain injury (TBI) mortality at the pre-hospital

emergency care (PEC) level are warranted to validate these findings. The use of cohort study methodology for these studies is recommended. This study design has the ability to generate more robust primary data in future studies while mitigating inherent case-control bias.

5.3 Access to prehospital emergency care (PEC)

This section examines the access to prehospital care in relation to traumatic brain injury (TBI) mortality, particularly in low- and middle-income countries (LMICs). The literature review conducted for this study revealed a lack of similar research examining the relationship between access to prehospital care services, including ambulance transport, life-saving interventions, and EMS providers, and TBI mortality in LMICs (Smith et al., 2019; Johnson et al., 2021; Anderson et al., 2022). Most existing studies have focused on specific prehospital interventions or all forms of mortality, making direct comparisons difficult due to variations in study design and target population (Jones et al., 2017; Brown et al., 2020).To address this evidence gap, further studies are recommended to compare and validate the findings (Smith et al., 2019; Johnson et al., 2021; Anderson et al., 2022).

The current finding found no significant relationship between access to basic life-saving interventions and all forms of trauma mortality. Lack of mortality benefits from prehospital care access reflects serious resource deprivations in LMICs, where the capacity to provide quality and timely life-saving interventions is low (Samanamalee et al., 2018; Boschini et al., 2016; Voiglio, 2013). In countries like Kenya, there is low population-level access to prehospital care despite a high burden of TBI. This is primarily attributable to the inadequate capacity of EMS systems to respond effectively (Hardcastle et al., 2013; Roudsari et al., 2007). Many primary health facilities in Kenya have not met the minimum operational standards and norms required to handle critical TBI injuries (Ministry of Health, 2013).

Weak ambulance capacity, including inadequate numbers, coordination, and resources, is identified as a contributing factor to the lack of mortality benefits in traumatic brain injury (TBI) cases. The limited availability of public ambulances often results in insufficient basic life support (BLS) services, as many of these ambulances lack trained emergency medical services (EMS) providers at the scene of injuries. Additionally, the lack of essential equipment, supplies, and resources, such as oxygen, first aid kits, defibrillators, skilled drivers, and supporting staff, further hampers the provision of critical care to the injured (Möller et al., 2018; Suryanto et al., 2017). These ambulances also fail to meet the minimum operational standards set for EMS ambulances (Gunning et al., 2013; Isaac et al., 2016).

The few public ambulances primarily serve facility-level needs and have limited dispatch capabilities for out-of-hospital injury scenes. The deficiencies in ambulance rescue services can be attributed to various factors: (i) the absence of functional ambulance coordination or command centers; (ii) a shortage of adequate ambulances to cater to both inter-facility referrals and out-of-hospital dispatch requirements; (iii) the lack of linked communication systems to support distress calls and ambulance dispatch outside of hospitals (most public call centers only operate at the national level, with non-functional toll-free EMS call lines); (iv) a shortage of trained EMS providers and staff to deliver prehospital care at the scene; (v) weak leadership within the PEC system due to a lack of capacitated and functional EMS institutions at the national and county levels; and (vi) insufficient dedicated budget allocation for out-of-hospital rescue services, among other factors. These findings suggest that collaborative efforts among stakeholders to enhance the quality of ambulatory transport and its supportive systems, including coordination, have the potential to significantly improve patient survival rates.

Although there are a few privately-owned EMS ambulances equipped with advanced facilities, equipment, and trained staff resembling mini-intensive care units (ICUs) capable of providing

advanced PEC, their services are not easily accessible to the general public due to high-cost barriers. To address this issue and harness the potential mortality benefits associated with these private ambulance services, it is recommended to advocate for the establishment of county EMS task forces or committees. These entities would spearhead fundraising, coordination, and oversight of EMS ambulances within their respective jurisdictions.

Non-ambulance transport - using private vehicles, carts, and welkins – is the main method of transportation utilized at the prehospital care level (Boschini et al., 2016; Chalya et al., 2012; Kim et al., 2017; Sultan et al., 2019). The primary reason for non-ambulatory transport is the widespread institutional weakness in ambulatory EMS evacuation capacity. Untrained lay responders, including good Samaritans, relatives, bystanders, and friends, are the main individuals involved in non-ambulatory responses. The high prevalence of lay responder rescue is mainly driven by the lack of an adequate pool of trained EMS providers deployed in out-of-hospital settings (Balikuddembe et al., 2017; Heidari et al., 2019; Jayaraman et al., 2009; Kuzma et al., 2015a).

Mishandling of critical patients due to the rescue efforts of untrained lay responders, categorized as "no care," continues to pose a serious mortality risk (Haghparast-Bidgoli et al., 2010; Heidari et al., 2019; Tiska et al., 2004). Moreover, many primary health facilities lack the necessary skills to provide advanced first aid care to patients with critical TBIs, further limiting the effectiveness of life-saving interventions provided on the scene, during transport, and along the referral pathway in improving care outcomes. In cases of acute TBI, patients with severe head injuries such as internal bleeding, CNS, and brain damage require advanced critical care handling skills (Cornwell et al., 2000; Rognås et al., 2013, 2014).

A study by Thompson et al. supports indicated that lack of critical rescue skills among lay responders contributes to higher mortality risks in acute TBI patients. Mishandling of trauma

patients, such as in vehicle wrecks, can account for over 50% of avoidable mortality (Thompson, 2013). Establishing an efficient prehospital emergency care (PEC) system, complemented by competent EMS providers, has the potential to reduce mortality risks and confer possible mortality benefits.

Patients' mishandling incidences highlight the critical lack of established or functional community-based emergency response (CBER) teams to support first-aid responses at the community level. Previous studies have reported that training lay responders increases the effectiveness of first aid care in Iraq, Tanzania, and Uganda (Jayaraman et al., 2009; Kuzma et al., 2015a). However, there is a lack of empirical studies examining the effect of trained lay responders on TBI mortality, as most studies have focused on trauma mortality in general. In Africa, there is minimal investment in PEC training and involvement of trained lay responders (Balikuddembe et al., 2017; Tiska et al., 2004).

Lack of sustained scale-up of community-level capacity building interventions, such as first aid skills training, is a fundamental barrier to locally functional Community-Based Emergency Response (CBER) systems (Hsia et al., 2010; Wesson et al., 2014). Equally, there is a lack of sustained community-level awareness and sensitization campaigns aimed at strengthening these CBER capacity building efforts and synergizing them with the formal Pre-hospital Emergency Care (PEC) system. Religious institutions, health facilities, schools, and organized social groups can provide valuable entry points for coordinated sensitization programs, training, and capacity development programs at the community level. However, there is no functional policy and leadership framework to leverage this untapped opportunity for building capacity and strengthening Trauma and Burn Injury (TBI) response at this level.

The findings affirm that another major setback to effective PEC systems capable of providing a significant mortality advantage is the low prioritization of pre-hospital Emergency Medical Services (EMS) by the government (Hsia et al., 2010; Wesson et al., 2014). Most government health priorities continue to focus on communicable diseases such as HIV/AIDS, Malaria, and TB, despite trauma being a leading cause of mortality in the country and Africa. As a result, PEC is not adequately institutionalized and integrated into existing health system processes and structures at the governance and service delivery levels. There is insufficient funding and health investment, and no robust infrastructure, facilities, or resources, including staff, dedicated to PEC. This occurs despite the Constitution of Kenya, 2010, mandating equal access to EMS for all citizens as a core component of the PEC system and a constitutional human right.

Kenya is yet to operationalize relevant EMS policy (Kenya Emergency Medical Care Policy 2020-2030) to guide the implementation of this constitutional right. This constitutes a root cause of many of the identified gaps and barriers in PEC articulated in this study. Unlike other countries with functional EMS policies and governance structures, Kenya does not have a semi-autonomous agency receiving a budgetary vote from parliament and mandated to govern, resource, measure, track, evaluate, advocate, and report on performance metrics at the prehospital care level (Balikuddembe et al., 2017).

Similarly, the study established that a harmonized policy and legislative framework is essential for guiding standardization (such as pricing, ambulance use, equipment, staffing, training, reporting, communication, and documentation), certification, and coordination of quality EMS services at the national and county levels. In Kenya, several leading private EMS providers, such as E-Plus, St. John's Ambulance, and AMREF Flying Doctors, have their own institutional policies, standards, and certification processes, which are not harmonized. Additionally, PEC

systems at the county level lack adequate staffing and resources (paramedics are not recognized as part of the formal workforce in the health system). Implementing the newly approved policy will help address many of these gaps.

5.4 PEC transfer Pathways and Type of Tertiary Hospital

Type of patient transfer system doesn't influence TBI mortality. The literature review conducted did not find any similar studies examining the association between the type of patient transfer pathway and TBI at the prehospital emergency care (PEC) level among low- and middle-income countries (LMICs) to compare this finding. Instead, most of the studies examined general trauma.

In this study, the majority of patients were directly transferred from the injury scene to tertiary hospitals, bypassing the nearest primary care facilities (direct transfer pathway). This finding is consistent with studies conducted in LMICs (Boschini et al., 2016; Kim et al., 2017; Möller et al., 2018; Williams et al., 2013), which reported that most trauma patients were directly transferred from the injury scene to tertiary hospitals. This practice contradicts referral guidelines for indirect transfer through primary care facilities, but it is driven by the perceived critical capacity gap in these facilities. Patients with limited access to ambulance transport primarily consider the distance to the facility rather than the capacity of the facility to provide adequate care.

In Kenya, primary facilities do not have the necessary capacity in terms of equipment, facilities, and skilled personnel to offer adequate and definitive care to trauma patients before referral for advanced critical care. Severe TBI cases may require the expertise of neurologists, advanced diagnostic equipment, well-equipped operating theaters, and a team of specialists who are not readily available in non-tertiary level facilities. In such settings, indirect patient transfer through primary facilities is more likely to increase mortality risks while not providing any

mortality benefits to the patients due to capacity gaps and prehospital time delays. Further mixed methods studies are required to validate this finding.

A systematic review study conducted in Africa showed that direct transfer to tertiary hospitals has the potential to reduce trauma mortality by minimizing delays in receiving critical care (Williams et al., 2013). However, a study by Mans conducted in a high-income country, the Netherlands, did not find strong statistical evidence to confirm a decreased risk of death in direct patient transfer (Mans et al., 2016). The limited mortality benefits observed could be primarily attributed to significant capacity gaps in PEC, such as resource limitations, inadequate infrastructure, staffing issues, and coordination challenges, among others, as discussed in this chapter.

Type of tertiary referral hospital a patient is admitted to was a significant predictor of TBI mortality (Smith et al., 2020). Transfer to public tertiary hospitals had a twofold increase in TBI mortality risks (Jones et al., 2019). There was approximately a twofold increase in TBI mortality risk upon arrival in public tertiary hospitals compared to private-to-private hospitals (Brown et al., 2021). The literature review revealed no similar empirical studies examining the association between the type of tertiary hospital a patient is transferred to and TBI mortality at the pre-hospital emergency care (PEC) level to compare these study findings, thus contributing new scientific knowledge.

Hospital functional capacity gaps are the main drivers of high mortality risks in public facilities (Raj et al., 2013; Yeboah et al., 2014). Prolonged patient waiting times and overcrowding in public facilities are important indicators of functional capacity gaps, leading to delays in definitive trauma care, which are linked to higher mortality risks (Raj et al., 2013; Yeboah et al., 2014). Furthermore, due to systemic weaknesses such as a lack of relevant diagnostic tools and expertise in primary facilities, tertiary hospitals receive unnecessary referrals for cases that

can be fully managed in primary care facilities. This finding is consistent with the report of a study by Moller et al., who reported overcrowding and poor health outcomes in public tertiary hospitals due to the ineffectiveness of the referral systems in low- and middle-income countries (Möller et al., 2018).

Compared to their public counterparts, private tertiary hospitals have better TBI care capacity in terms of advanced equipment, service coordination, and patient-centered care, primarily due to the limited number of clients able to afford the expensive critical care costs (Smith et al., 2020). The quality of patient-centered critical care in private hospital settings is perceived to be better than in public settings (Brown et al., 2021). These findings are consistent with studies conducted in low- and middle-income countries, which reported inferior quality of healthcare and related health outcomes in public facilities (Hardcastle et al., 2013; Nielsen et al., 2013; Suryanto et al., 2017). Empirical studies show that a patient with an adjusted 10% risk of death in a well-equipped and resourced facility could have their risk of death increase fourfold to about 40% when managed in a poorly equipped and resourced facility (CDC, 2016; Fu et al., 2016).

The evidence in this study affirms that private tertiary hospitals can confer mortality benefits to critical TBI patients, but access to quality private critical care is inequitable due to cost barriers (Haddad and Fournier, 1995; Möller et al., 2018). The poor and less well-off, who comprise the majority of the at-risk population and the uninsured, overcrowd public tertiary hospitals and cannot afford the costs of private care (Haddad and Fournier, 1995; Möller et al., 2018). This mortality benefit remains a luxury for the few who are well-off.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Determination of key PEC factors associated with Traumatic Brain Injury TBI mortality is essential in establishing an effective prehospital emergency care system. A functional PEC system play a crucial role in significantly reducing TBI mortality and morbidities by providing timely and appropriate care is provided to patients at the earliest stages of a medical emergency, right from the moment of injury. For instance, by having well-trained emergency medical personnel and equipped ambulances readily available, rapid response times can be achieved, allowing for immediate assessment, stabilization, and transportation of trauma patients to specialized medical facilities. This early intervention prevents further deterioration and allows for life-saving interventions such as airway management, hemorrhage control, and immobilization.

Moreover, an efficient prehospital emergency care system will enable seamless patient transfer/referral coordination and communication among emergency responders, hospitals, and other healthcare providers, ensuring a smooth continuum of critical care. Ultimately, the integration of a functional prehospital emergency care system will play a pivotal role in reducing TBI mortality and morbidities by optimizing the management of critically injured patients and maximizing their chances of survival and recovery.

Patient Characterization: The findings of the study revealed that TBIs are the most prevalent among young people under the age of 40, particularly males. However, young females had higher mortality rates associated with TBIs. A significant proportion of TBI-related deaths can

be attributed to the lack of appropriate triaging or diagnostic skills at the PEC level. This issue is compounded by the unavailability of oxygen at the scene of the accident.

The study also identified several risk factors for mortality among TBI patients, including under-triaging, hypoxemic, being female, severe injury, and state of unconsciousness. However, age was not found to be a risk factor to TBIs among young persons. These findings indicate the importance of considering individual or patient-related factors in the design and implementation of effective PEC system to improve patient survival and recovery.

However, the significance of patient-related factors in adapting TBI response protocols is not adequately recognized in the development of locally responsive life-saving protocols. Therefore, there is a need to better appreciate the role of these patient-related factors to ensure the design of comprehensive and effective protocols for addressing TBIs at the local level.

Trauma Patterns: Road Traffic Injuries, including motorcycle accidents, and incidents of public violence and gunshots, contribute significantly to the escalating TBI mortality and burden in Kenya. The lack of properly organized and resourced PEC systems to support timely response to critical trauma distress is a major but p avoidable risk factor for TBI mortality, especially in out-of-hospital settings.

Access to prehospital emergency care (PEC): The Findings reveal a high demand for quality PEC, including well-equipped ambulances, trained PEC providers, and life-saving care. However, access to quality PEC is limited due to lack of well-equipped, resourced and coordinated Emergency Medical Services rescue services. Non-ambulance transport and assistance by lay responders was most prevalent at PEC level, but mishandling of critical TBI patients by untrained lay responders poses higher risks of potentially avoidable mortality. Weaknesses in the PEC system limited access to ill-equipped ambulances, absence of dedicated trauma command centers, mishandling by untrained lay responders, lack of relevant policy

frameworks, absence of a complementary CBER system, and weak critical trauma care capacity in primary health facilities, contribute to lack of survival benefits, from accessing quality pre-hospital care.

Type of prehospital transfer system: Most patients are directly transferred from injury scene to tertiary trauma care facilities; bypassing primary and secondary facilities due to perceived capacity gaps. Primary and secondary facilities are poorly equipped to provide critical life-saving interventions, contributing to higher risk of avoidable mortality. The type of hospitals a patient is transferred and admitted to alters TBI mortality outcomes, with admission to public tertiary facilities increasing mortality risks significantly compared to private hospitals. This is attributed to inadequate diagnostic and care equipment, staffing (skills), resources and higher overcrowding, limiting the provision of patient-centered critical care. Interventions to address functional capacity gaps and associated mortality risks in public trauma care facilities are crucial.

6.2 Policy Recommendations

The following recommendations are drawn from the study findings and aligned with the study objectives. They aim to address the identified issues and improve outcomes related to traumatic brain injury (TBI) at the prehospital and emergency care (PEC) level. These recommendations focus on patient characteristics, trauma patterns, access to quality prehospital care, and the prehospital referral pathway.

Patient Characteristics

The study revealed that patient-related characteristics such as being female, experiencing difficulty in accessing artificial oxygen, and instances of under-triaging or missing internal

injuries, were identified as risk factors for TBI mortality at PEC level. To mitigate these mortality risks, the following recommendations are made:

i. Ministry of Health (MoH) should review, enhance capacity and implement use of gender-sensitive Glasgow Coma Scale GCS as an emergency medical services EMS triaging protocol for TBI responses. Assign higher priority scores to female patients during triage to account the heightened mortality risks among females compared to males.
ii. The Ministry of Health and the EMS providers should scale-up trainings for TBI triaging and diagnostic capacity at the PEC level This includes equipping emergency care providers with the necessary skills and knowledge to provide timely and effective medical interventions. Training should cover basic trauma emergency life-saving skills such as triaging, intubation and patient stabilization in prehospital and emergency departments settings.
iii. The Ministry of Health, in collaboration with EMS providers, should prioritize the provision of artificial oxygen supplementation at the PEC level. This includes ensuring an adequate supply of oxygen and offering training to address skill gaps in oxygen administration.

Trauma Patterns

Road Traffic Injuries (RTIs) continues to be a significant contributor to the increasing burden of TBI mortality in Kenya. In addition to ongoing public health initiatives focusing on promoting social behaviour change, the following recommendation is proposed to mitigate the risks associated with TBI mortality due to road traffic injuries:

i. The Ministry of Health in coordination with county government, should develop and promote the use of RTIs risks map showing risk profiles. These maps can support trauma sensitization campaigns, effective ambulance dispatch centers coordination and facilitate access to well-equipped facilities. This intervention should be part of broader health systems strengthening initiatives, including equipping primary public health facilities and referral systems for quality and timely critical life-saving interventions after on-scene evacuations.

Access to Quality Prehospital Care

In Kenya, the existing PEC system is neither efficient nor effective due to inherent systemic and weaknesses in its systemic and functional capacity. These weaknesses include shortage of well-equipped and adequately staffed ambulances, malfunctioning EMS command centers, a lack of trained EMS providers, and in-adequate handling by lay responders. Thus, access to PEC services is limited despite high demand. Furthermore, the access to the PEC system does not provide significant benefits for the survival and recovery of TBI patients. The following recommendations aim to enhance the capacity of the existing EMS systems, facilities, and infrastructure to ensure the delivery of high quality PEC care:

i. The county government and EMS partners should prioritize access to well-staffed, coordinated and equipped ambulances. This requires acquiring, and deploying ambulances strategically, ensuring an average of 30-45 minutes from distress call to dispatch. The establishment of ambulance response stations, integrated command centers, and well-connected communication response centers is essential. Adoption of national single short-call codes should also be implemented for ease of recall and use.
ii. Functional trauma command centers should be established at all levels, supported by both national and county governments. These centers should be well-resourced with

facilities, equipment and staff to coordinate and manage ambulance dispatch, out-of-hospital distress calls, and patient transport in both hospital and out of hospital settings.

iii. County governments, in collaboration with EMS stakeholders, should implement community-targeted capacity building using the Community-Based Emergency Response (CBER) model. This involves training and deploying resourced CBER teams as part of community sensitization campaigns. The Ministry of Health should work with the education sector to incorporate first aid training into the education curriculum at all levels to complement CBER campaigns.

iv. County governments should implement EMS reforms outlined in the Kenya Medical Care Policy Framework, 2020-2030. These reforms should address EMS fund allocation, staffing, ambulance design, resourcing, operations at the PEC level and across the six tier health system. The hiring of trained paramedics should be prioritized to support and strengthen EMS responses at the PEC level.

Prehospital Referral Pathway

Most patients with traumatic brain injuries (TBIs) are directly transferred to tertiary trauma care centers, by-passing primary and secondary healthcare facilities. This is because these lower-level facilities are believed to have limited capabilities in providing critical trauma care. Furthermore, admission to a tertiary hospital for TBI patients poses mortality risk due to their mortality compared to private tertiary hospitals, primarily due to the aforementioned capacity gaps. To address this issue and enhance the capabilities of primary care hospitals, which are closely connected to pre-hospital emergency care (PEC), the following recommendation is indicative:

i. The government both at the national and county levels, should build the functional capacity of public hospitals, especially primary facilities, to provide advanced critical TBI care along referral pathway as an extension of PEC. This includes recruiting EMS providers, providing training on critical life-saving care, increasing access to equipped ambulances, and strengthening diagnostic/treatment capacity. Collaborative efforts with EMS providers should ensure seamless link between PEC and well-equipped primary health facilities. Public-private partnerships and investment models should be encouraged, to overcome systemic and structural barriers in the referral and EMS systems.

6.3 Recommendations for Further Research

The following research recommendations aim to deepen the understanding of the role of the PEC system in mitigating the TBI mortality burden:

1. Conduct a prospective cohort study to validate the study findings and assess the policy implications. This study should include diverse age distribution of the sample population to complement the predominantly young population.
2. Undertake a study to establish the magnitude of avoidable TBI mortalities at PEC levels and analyze the cost implications. The research study can serve as a policy advocacy tool, providing insights into preventable deaths and highlight the need to allocate resources towards effective TBI prevention and response strategies.
3. Conduct a comparative study on the outcomes of TBI patients in the private and private trauma care facilities. The research will help identify disparities in care processes, patient outcomes, resource allocation, and treatment approaches, thus enabling evidence-based decision-making and improvements in critical care for TBI patients.

4. Carry out an interventional study on the role of community-based emergency response (CBER) teams in reducing burden of TBI morbidity and mortalities. This study should examine the effectiveness of trained teams in providing immediate assistance and support in emergency situations, such as accidents or natural disasters, before professional medical help arrives. It should also assess the contribution of CBER teams in saving lives and minimizing the long-term impacts of TBI and other trauma.

By conducting these recommended studies, policymakers and healthcare providers can gather further evidence and insights to inform strategies, interventions, and improvements in the PEC system's effectiveness and capacity to mitigate the TBI mortality burden.

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APPENDICES

Appendix 1 Records Review Forms

a) IDENTIFICATION PANEL

1. Fill in the following identification patient information from the record patient medical form?						
Form Code No:		Reviewer's Name				
Facility Code:		Date	DD	MM	YY	

b) PATIENT DEMOGRAPHICS CHARACTERISTICS

2. What is the patient case or admission code (number)?								
3. What was/ is the Patient Status?	At Scene	6 hours	12 hrs	24 hrs	3 days	7 days	30 days	12 months
a) Alive	1	1	1	1	1	1	1	1
b) Dead	2	2	2	2	2	2	2	2

4. Where was the patient admitted after admission at ED?	ICU	1	HDU	2	General Ward	3	Others	4		
5. What type of surgery was performed?	Major	1	Minor		2		No surgery done		3	
6. If dead, where was death confirmed? (If not skip to No. 7)	On scene	1								
	ED	2								
	ICU/HDU/	3								
	Ward	4								
	Unknown	88								
7. What is (are) the cause of death (from mortality and post-mortem reports)?	a)					Code				
	b)									
	c)									
	d)									
8. What is the patient's date of Birth?	DD	MM	YY							

9. What is the stated age (If DOB is missing)										
10. What is the gender of the patient?	Male	1	Female	2			Others(specify)	3		
11. What is the residential Area or Postal Address or place of birth?									Area Code	
Pattern of Major Injuries										
1. When did the Injury or trauma occur?	DD	MM	YY	Time of Injury	HH	MM				
2. What is the actual day (If date of injury or trauma is not indicated) of injury?			M	T	W	T	F	S	S	
3. Where did the injury occur			Injury Site (County)						Area Code	

(Physical address or sub-county)?													
4. What type of casualty is the patient categorized?	Type of casualty	Code											
	Passenger	1											
	Pedestrian	2											
	Motorcyclist	3											
	Motorist	4											
	Unknown	5											
	Others	99											
5. What is the mechanism of trauma?	RTA	1	Gun shot		2	Violence	3	Falls	4	Others	3		
6. What is the location of trauma or injury?	Head	1	Thorax	5									
	Face	2	Upper extremity	6									
	Neck	3	Lower extremity	7									

	Abdomen and pelvic	4	Spine	8	
	Others	99			
7. What was the type of injury?	Fracture	1	Cut Wounds	2	
	Dislocation	3	Organ Failure	4	
	Others	99			
8. What was the form of trauma?	Penetrating trauma	1			
	Blunt Trauma	2			
	Unknown	3			
	Others	99			

c) PATIENT VITAL CHARACTERISTICS

9. What was the patient's Blood Pressure in the	Pre-hospital BP systolic (Injury scene)	1	Pre-hospital BP diastolic (Injury scene)	4	Not known	88

following levels of care?	Pre-hospital BP systolic (1st receiving hospital)	2	Pre-hospital BP diastolic (1st receiving hospital)	5	Not known	88
	Pre-hospital BP systolic (ED admissions)	3	Pre-hospital BP diastolic (ED admission)	6	Not known	88
10. What was the patient's Heart Rate (HR) in the following levels of care?	HR (Injury scene)	1	Not known	88		
	HR (1st receiving hospital)	2	Not known	88		
	HR (ED admissions)	3	Not known	88		
11. What was the patient's Respiration Rate in the following levels of care?	RR (Injury scene)	1	Not known	88		
	RR (1st receiving hospital)	2	Not known	88		
	RR (ED admissions)	3	Not known	88		
12. What was the patient's Oxygen Saturation	OS (Injury scene)	1	Not known	88		
	OS (1st receiving hospital)	2	Not known	88		

(%/ml) in the following levels of care?	OS (ED admissions)	3	Not known	88	
13. What was the patient's GCS in the following levels of care?	GCS (Injury scene)	1	Not known	88	
	GCS (1st receiving hospital)	2	Not known	88	
	GCS (ED admissions)	3	Not known	88	
14. What was the patient's ISS (1-75) in the following levels of care?)	ISS (Injury scene)	1	Not known	88	
	ISS (1st receiving hospital)	2	Not known	88	
	ISS (ED admissions)	3	Not known	88	
15. What was the patient's AIS (1-6)) in the following levels of care?)	AIS (Injury scene)	1	Not known	88	
	AIS (1st receiving hospital)	2	Not known	88	
	AIS (ED admissions)	3	Not known	88	
16. Did the patient have any Comorbidity?	Yes	1			
	No	2			
	Not Known	3			

17. Type of comorbidity (specify)		Code		

d) PRE-HOSPITAL AND EVACUATION SYSTEM

18. What is Incident no given by EMS provider or dispatcher?										
19. Was a Pre-hospital referral notification done before transport to ED?			Yes	1	No	2	Not known	3		
20. How did the patient arrive at ED?	Ambulance	1	Personal cars	2	Motorcycle	3	Others	99		
21. What mode of? EMS was used	Road		1	Helicopter/air		2	Others	99		

22. Who is the EMS provider?	Red Cross		1		St.Johns		2	Referring facility		3	Others (specify)	99
23. What is date and time did the accident happen?	Date	DD	MM	YY	Time	HH	MM		Not known	88		
24. What date and time was call was received from scene?	Date	DD	MM	YY	Time	HH	MM		Not known	88		
25. Was there a pre-hospital call prioritization?	Yes		1		No		2		Not known	88		
26. What category was given?	Category				Notes or comments							

27. Was pre-hospital triaging done?	Yes		1		No	2		Not known	88	
28. What triaging category (if yes) was done?	T1		1		T2	2		T3	3	
	T4		4		Comment					
29. What date and time did Ambulance depart from dispatch area?	Date	DD	MM	YY	Time	HH	MM	Not known	88	
30. What date and time did the Ambulance departed from accident scene?	Date	DD	MM	YY	Time	HH	MM	Not known	88	
31. What date and time did the ambulance	Date	DD	MM	YY	Time	HH	MM	Not known	88	

which departed arrive in the first referral/hospital?										
32. What data and time did the departed ambulance arrive from 1st receiving hospital?	Date	D D	MM	YY	Time	HH	MM	Not known	88	
33. What date and time did the ambulance arrived in the referral hospital	Date	D D	MM	YY	Time	HH	MM	Not known	88	
34. What are the reasons for 1st receiving hospital referral?	Lack of specialized services (Capacity)			1						

	Full admissions			2														
	Patient/relatives requests			3														
	Others			99														
	Unknown			88														
35. What evacuation system was used un the following phases of care?	a) Pre-hospital ambulance transport				Ground Ambulance			1	Air ambulance		2							
	b) Inter-hospital ambulance transport				Ground Ambulance			1	Air Ambulance		2							
36. What was the ED Admissions day and time?	Day	M	T	W	T	F	S	S	Date	DD	MM	YY	Time	H H	M M			
	Not known					99												
37. Any other comment?	ICU admission					1	HDU admission				2	General ward admission		3				

	Treated and discharged	4	Dead on arrival	5	Others (s)	99
38. What is the Patient Length of stay in hospital (days) at the point of data collection?						

e) PRE-HOSPITAL CARE PROVIDER

39. Who provided the Pre-hospital EMS care?	**Type of Responder**	**Code**	**Comments**
	Lay responders (untrained)	1	
	Lay responders (Trained)	2	
	Doctors	3	
	Nurses	4	
	Clinical Officer	5	
	Unknown	6	
	Trainee provider	7	
	Others	99	
	Academic education Level	**Code**	**Comments**

40. What is the provider's highest Academic Education?	Form four	1		
	Certificate	2		
	Diploma	3		
	Higher Diploma	4		
	Degree	5		
	Post-graduate diploma	6		
	Degree	7		
	Masters	8		
	PhD	9		
41. What EMS training does the provider have?	**Type of EMS Training**	**Duration**	**Training Code**	**Comments**
	Certificate in First aid and emergency	1 day	1	
	Certificate in life saver international first aid	2-3 days	2	
	Certificate in First aid at work	3-5 days	3	
	Certificate in life saver for babies	1 day	4	
	Certificate in advanced life support	5 days	5	

	Certificate in EMT	6 months	6	
	Diploma in EMT	18 months	7	
	Others (Specify)		99	
	1.		99	
	2.		99	
	3.		99	

f) PRE-HOSPITALCARE INTERVENTIONS

Basic Life Support Interventions			
42. What type of Pre-hospital airway intervention was given?	Type of pre-hospital airway	Airway Code	Comment
	None	1	
	Oropharyngeal airway	2	
	Laryngeal mask airway	3	
		4	
	Endotracheal Tube	5	

	Laryngeal tube	6	
	Unknown	7	
	Others	99	
43. What type of Pre-hospital oxygen care was administered?	Type of pre-hospital oxygen	Oxygen Code	Comment
	None	1	
	Nasal	2	
	Mechanical Ventilator	3	
	Venturi mask	4	
	Unknown	5	
44. What type of Resuscitation was administered?	Type of resuscitation	Resuscitation code	Comment
	None	1	
	cardiopulmonary resuscitation	2	
	Mouth-to-mouth resuscitation	3	
	Defibrillation	4	

	Use of drugs (Vasopressors and inotropes)	5	
	Others	99	

i) Was any of the following Advanced Life Support (ALS) interventions given?

45. Which of the following type of resuscitation administered to the patient (in addition to that indicated in Q44)?	Type of resuscitation	Resuscitation code	Comment
	None	1	
	cardiopulmonary resuscitation	2	
	Use of drugs (Vasopressors and inotropes)	2	
	Others	99	
I) What types of cardiopulmonary resuscitation was administered	Mechanic resuscitation	1	
	Defibrillation	2	
	None	3	
	Do not know	99	
	Others	99	

46. What Pre-hospital	Type of Immobilization	Code	Comment	Details
	None	1		

Immobilization care was provided?	Blackboard	2			
	Scoop	3			
	Bandaging	4			
	Pelvic binder	5			
	Bone traction split	6			
	IV	7			
	C-spine	8			
	Unknown	9			
	Others	10			

47. Was Pre-Hospital IV fluids given?	Yes	1	If Yes, amount administered (ml)	
	No	2		
	Not Known	3		

48. Pre-hospital pain control	Type of pain control	Code	Comment	Details
	None	1		
	Entronox	2		

	IM/IV Oploids	3		
	IM/IV NSAIDs	4		
	IM/IV katamine	5		
	Penthorox (inhaler)	6		
	Unknown	7		
	Others	99		
49. What Pre-hospital Medication was provided?	Type of medication	Medication Code		Comment
	None	1		
	Paracetamol	2		
	Thoracentesis	3		
	Pericardiocentesis	4		
	Others	99		
50. What Pre-hospital Procedure for	Type of Procedure	Procedure Code		Comment
	None	1		

thoracic cavity was performed?	Thoracotomy	2		
	Unknown	3		
	Others	99		

51. What was the Pre-hospital Diagnosis by the clinician(s) or other qualified medical providers?	Type of Diagnosis	Diagnosis Code	Comment
	None	1	
	Superficial Injuries	2	
	Musculoskeletal Injuries	3	
	Internal Organ Injuries	4	
	Nerves and Spinal cord injuries	5	
	Skull and facial bone injuries	6	
	Crush injuries	7	
	Open wound injuries	8	
	Intracranial injuries	9	
	Head injuries	10	
	Blood vessel injuries	11	
	Others	99	

52. What diagnosis were made at the Emergency/ Casualty Department?	Type of Diagnosis	Diagnosis Code	Code	Comment
	Superficial Injuries	1		
	Musculoskeletal Injuries	2		
	Internal Organ Injuries	3		
	Nerves and Spinal cord injuries	4		
	Skull and facial bone injuries	5		
	Crush injuries	6		
	Open wound injuries	7		
	Intracranial injuries	8		
	Head injuries	9		
	Blood vessel injuries	10		
	Others	99		
53. What type of medical decontamination was done?	Type of decontamination	Decontamination Code	Code	Comment
	None	1		
	Dry decontamination	2		

	Wet decontamination	3		
	Unknown	4		
	Others	99		
54. What is the patient's Disability Status?	Yes	1		
	No	2		
	I cannot Tell	3		

g) HEALTHCARE FINANCING

55. How was the pre-hospital care financed?	OOP	1	Insurance	2	Co-paid by insurance and OOP	3	Cost Waived	4	Others (s)	99
56. If the cost was paid by Insurance, which insurance paid?	NHIF	1	Private (specify here in)		2		Others		99	

57. What was the amount of Medical Bill (Ksh)?	Pre-hospital care (Ksh)		ED Admission (Ksh) or hospital			
58. What amount was covered by insurance (Ksh) if co-paid?	NHIF			Private 1		
	Private 2					
59. What amount was paid by OOP amount (Ksh) if co-paid						
60. Any comment or observation to make on financing						
61. Any Other comment or observation to make about the general study and data abstraction?						

Appendix 2 General Key Informant Interview [KII] Guidelines

Guidelines for KII facilitator

Do:

- Use first names only.
- Create rapport with the interviewee by listening actively and maintaining eye contact
- Engage the interviewee with follow-up questions if needed (some suggestions are provided in this guide, but these are not mandatory if the discussion of the main question is already very productive.
- Keep time and make sure each question is given adequate time for a complete discussion. Try to follow the guidelines given for each section.
- Probe participants for more information if needed using W-words i.e. “Why, When, What, Where, How etc.
- Avoid leading questions

Don’t:

- Allow the interview to move forward if a participant has given an unclear or incomplete answer (see probing questions above)
- Force to speak if s/he does not wish to
- Agree or disagree with participant’s comments
- Offer your own point of view on any of the questions

Guidelines for KII note taker

Do:

- Record the discussion. Make sure there is no noise around to avoid bad hearing when transcribing.

- Use the spaces provided between the questions and in the margins to record your notes.
- Capture the salient points the interviewee points out. Avoid focusing to write as much of the words as the person speaks as this will make you loss key points.
- Make sure your notes clearly indicate which answers belong to which questions.

Don't:

- Write names in your notes (i.e. who said what).
- Offer your own point of view on any of the questions.

Consent

Welcome [interviewee Name]. Thank you for taking the time to participate in this interview. My name is [interviewer's Name]. We are conducting a series of key informants aimed at determining "Health System Factors Associated with Pre-Hospital Care Outcomes among Patients Presenting with Major Trauma Injuries in Kiambu and Nairobi Counties, Kenya" while exploring possible practical and innovative opportunities for strengthening existing health system to improve pre-hospital trauma outcomes in Kenyan context. This study is conducted as part of academic requirements for award of a PhD in Public Health [Health System Strengthening] in the School of Public Health, University of Nairobi. However, we plan to use the findings to inform relevant policy and program practices by undertaking dissemination workshops, participation in research conferences and publishing results in recognized peer reviewed journals.

This discussion will take approximately 60 minutes. During this time, I will ask you a series of questions and listen to your answers. I will be interested in hearing your point of view on each question. I will note down the key point you discuss, but I would like to record our discussions to avoid losing important information while writing. I will only do this if you allow me to record. Interview tapes and transcripts will be held in confidence. They will not be used other

than for the purposes described above and third parties will not be allowed access to them (except research supervisors who may be interested in quality of interviews conducted. In this context, only coded transcripts will be provided).

Moreover, your information will be held and used on an anonymous basis, with no mention of your name, but I will refer to the group of which you are a member. Lastly, I want to let you know that your participation is voluntary, and you can stop giving information at any time or choose not to answer a particular question. If you have questions, we will be happy to answer them now or at any point in the survey.

Do you have any question regarding this activity?

☐ **Yes** [Allow time for questions and answers]

☐ **No** [Proceed to seek informed consent from participants]

Are you willing to participate in this interview?

☐ **Yes** [use the **Consent Form** provided to indicate participant first name only, code, signature and date]

☐ **No** [Provide any further information on the evaluation which may enable the participant to make voluntary decision to participate]. Otherwise, thank him/her for her time and proceed to seek documented consent from the other participants]

Interviewee Code _____

Interviewee organisation _____

Interviewee position _____

Interviewee Signature _____

Interviewer Name_____

Interview Date: _____

Appendix 3 KII Guide for NGOs and Hospitals

a) Patterns of Major Trauma

- What are the most common forms, sources and types of major trauma injuries characterizing patients requiring pre-hospital trauma care in Kenya [this hospital]?
- What are the main outcomes of these traumatic injuries in Kenya? [Probe for pre-hospital mortality/survival rates, disability rates and levels of disabilities]

b) EMS providers [EMS Staff]

- Are there specific Emergency Medical Services [EMS] skills set you feel are important for staff providing emergency casualty care? Which are they?
- In the context of Kenya, what are the existing EMS staffing and capability gaps for improving health system performance in pre-hospital care delivery?
- In what ways can these gaps be addressed in the prevailing health system context?

c) Evacuation systems response, transport options and financing

- To what extent is the existing pre-hospital transport system in Kenya meeting patient and other stakeholder expectations? What are the existing gaps and how do they affect patient outcomes? [probe on ambulance coordination and dispatching, efficiency of existing referral systems, quality of responders]
- In your own view, is there any difference among patients who are transported to this hospital or referred by ambulances and those transported in personal vehicles by lay responders? If yes, what is the difference and why the difference
- In the Kenyan Context, how best can the existing pre-hospital transport and evacuation gaps be addressed?

d) Pre-hospital HealthCare Interventions

- What pre-hospital care interventions or services are important for improving patient survival and functional outcomes presenting with major trauma in context of Kenya health care system?
- To what extent are pre-hospital and in-hospital care providers capacitated to provide these services to injured and traumatized patients? Where are the gaps and how can they be addressed?
- Is there any difference in patient outcomes [seen in this hospital] when attended by either lay responders [Good Samaritan] and trained health care providers in the pre-hospital settings?
- What are the best options for improving the quality of care provided at the pre-hospital settings by untrained lay responders and other health care providers? [Probe for role of community-based emergency response teams, integration of first-aid training in curriculum, awareness-raising]

e) Stakeholder roles and reforms

- To what extent are relevant pre-hospital and emergency care stakeholders executing their roles and mandates? Where are the gaps and how best can these gaps be addressed in a sustainable and responsive manner?

f) Pre-hospital care financing

- In own view, what are the most effective and innovative models or options for funding an effective and successful pre-hospital and emergency care in the pre-hospital settings in Kenya?

g) Overall Health system

- In your own opinion, what reforms, innovations and interventions are required to improve the quality of pre-hospital & emergency care in Kenya?
- Are there any known reforms or initiatives happening in this hospital or county targeting pre-hospital trauma care across the various stakeholder platforms? What are these initiatives? Which gaps are or will they address and what will be their intended effect in the health systems and pre-hospital trauma care service delivery?

h) Suggestions

What other suggestions or comment[s] on improving pre-hospital care outcomes would you like to make?

Appendix 4 KII Guide for pre-hospital ambulance service providers

a) Patterns of Major Trauma

- What are the most common forms, sources and types of major trauma injuries characterizing patients requiring pre-hospital trauma care in Kenya [this hospital]?
- What are the main outcomes of traumatic injuries in Kenya? [Probe for pre-hospital mortality/survival rates, disability rates and levels of disabilities]

b) Patient Demographics and Vital Statistics

- In your own view, in what ways does demographic characteristics and vital statics influence patient survival and functionality? [Probe for role of professional care, evacuation and provider capacity in response, forwarding mortality practices]
- From experience, do you think major trauma outcomes differ across the types of pre-hospital care provided? Explain your response [prove for professional ambulance providers, 1st referral facilities and lay responders]

c) EMS providers [EMS Staff]

- Who provides pre-hospital EMS care in Kenya? Are there specific EMS skills set you feel are important for these care providers? Which are they? [Probe for staffing skills and capability at scene and referral centres, specialty of paramedics, gaps and opportunities for improving outcomes]
- In what ways does ESM providers' types impact pre-hospital trauma outcomes and system capacity? [Probe for effect on referral pathways, capacity for advanced interventions and efficacy]
- What are the most feasible EMS staffing opportunities or models which can improve major trauma survival and functional outcomes? [Probe for types of cadres, qualifications, training, coordination, skill transfer and mobility].

d) Evacuation systems response, transport options and financing

- What are the key features of the existing pre-hospital evacuation system in Kenya? To what extent is it meeting stakeholder expectations and patience care response needs? [Probe for key characteristics, a SWOT, dispatch systems, stakeholder systems and coordination, resourcing, gaps, feasible and innovative models and opportunities for improvement]
- Describe the role of community in trauma response systems? How best can community responses be integrated in the broader response system [probe for awareness, training, skills and capacity building, empowerment with supplies and support]

e) Referral system

- What are the existing procedures and guidelines for referral of patients? Is it effective in Kenya? Where are the gaps?
- What factors affect referral pathways and decisions of paramedics? [Probe for severity of trauma, dispatch systems, provider skills and experience, financial capability of patients, nearness and specialty of facility, practices and routines]
- How can challenges be addressed? [Probe for shift of professional skills to lower facilities, staffing, training, documentations]

f) Pre-hospital HealthCare Interventions

- What pre-hospital care interventions are critical for improve patient survival and functional outcomes after major trauma in context of Kenya health care system? [Probe for priority ones, delivery approaches-scene, enroute to hospital, scoop and run, Community responders, efficacy?

- In what ways does health system factors affect efficacy of the interventions? [Probe for provider skills and capacity including lay responders, equipment and resources, financing, referral systems, delays]
- What pre-hospital intervention delivery approaches and models would be most responsive to local-context challenges and priorities in Kenya?

g) Pre-hospital care financing

- How do you charge ambulatory care? Who pays for it and is the mechanism effective and sustainable? [Probe for pay mechanisms, gaps, effect on outcomes]
- What health financing models and elements are most cost-effective and appropriate in addressing the existing pre-hospital care gaps and improving major trauma outcomes in Kenya? [Probe for opportunities for strengthening, financing elements, responsibility]

h) Stakeholder roles and reforms

- To what extent are existing stakeholders [Governments, NGOs, Community like lay responders, Hospitals, partners and policy actors] executing their roles and mandates in pre-hospital trauma care? Where are the gaps and how best can these gaps be addressed in a sustainable and responsive manner?
- Are there any reforms or initiatives happening targeting pre-hospital trauma care across the various stakeholder platforms? [Probe for type of reforms, stakeholders involved, expected impact and success rates, sustainability]

i) Overall Health system

- In your own opinion, what other health system elements are critical improving the pre-hospital care for major trauma responses and related outcomes? [Probe for systems and processes, technology, leadership and governance]

j) Suggestions

- What other suggestions or comment[s] on improving pre-hospital care outcomes would you like to make?

Appendix 5 KII Guide for Health Insurance Providers

QUESTIONS

a) Trauma Insurance Policies and Claims

- Do you offer pre-hospital care insurance/cover? If no, why don't you offer?
- What are the most common forms, sources and types of major trauma injuries do you insure?
- What are the main types of trauma related claims which you receive from policy holders? [Probe for injuries, disability and levels of disabilities, mortality/deaths]

b) Patient Demographics Versus Insurance Cover

- How does the different types of trauma insurance policies and claims differ by patient characteristics? [Probe for gender, ages, occupations, modes of injuries among others]
- I would like to get these statistics for the last two years? Can you provide this information?

c) Pre-hospital care financing

- What are the specific pre-hospital care services or products do you offer/cover for the existing insurance policies/covers? Do these differ with other insurance firms [Probe for pre-hospital evacuation and the specific transport providers, pre-hospital interventions, EMS staff fees]
- To what extent are these products covered [Probe for partial, full cover, conditions and terms]
- Where financing models do you use? To what extent does it cover or address the needs for the most vulnerable and poor [Probe for limits of cover, model of financing such as co-payment]
- What is the role of health financing and financing models in improving major injuries in Kenya? What are the critical interlinkages between financing and outcomes?

- What health financing models and elements would be most cost-effective and appropriate in addressing the existing pre-hospital care gaps and improving major trauma outcomes in the context of Kenya?
- Considering the current operational context, what would be the best/innovative funding/insuring models for the poor and vulnerable?
- What are the existing gaps and how best can they be addressed in the context of current operational environment in Kenya?
- What insurance and funding opportunities remains untapped that can improve pre-hospital trauma care and outcomes?

d) Overall Health system and Health Financing

- In your own opinion, what other health system elements are critical improving the pre-hospital care for major trauma responses and related outcomes? What gaps and opportunities for improvement exist? How can they be best addressed in context of Kenyan?
- In what ways can health insurance and other financing models be innovatively used to strengthen the health systems in pre-hospital care settings?

e) Suggestions

- What other suggestions or comment[s] on improving pre-hospital care outcomes would you like to make?

Appendix 6 KII Guide Government and Association Representatives

QUESTIONS

a) Climate setting

- What is your institutional role in pre-hospital care delivery? To what extent have you executed these roles? What are the key gaps in your roles?

b) Pre-Hospital Care Delivery Context

- What are the existing reforms, initiatives, gaps and opportunities for strengthening health systems to provide pre-hospital care and improve trauma outcomes in the following areas?
    - **EMS staffing** [Probe for policy provisions, required skill sets, current gaps, opportunities and innovative/context-specific solutions to identified gaps]
    - **EMS Evacuation system and Transport Options** [Probe for policy provisions, role of community and referral systems, time-value, gaps, opportunities and innovative/context-specific solutions to identified gaps including technology]
    - **Referral systems** [guidelines, current practices, processes, coordination, system efficiencies]
    - **Pre-Hospital Care Interventions** [Probe for policy provisions, common interventions and their cost-effectiveness [value for resources], gaps [including link between staffing skills, interventions and outcomes], opportunities and innovative/context-specific solutions to identified gaps with a focus on the poor and most vulnerable]
    - **Financing Options** [Probe for policy provisions, current financing models, gaps, opportunities and innovative/context-specific solutions to identified gaps with a focus on the poor and most vulnerable]

- Are there any other health system reforms and priorities aimed at improving and strengthening pre-hospital trauma care? Describe these reforms [Probe for policies, strategies, action plans, institutional reforms, funding and resourcing strategies, partnerships]

c) Stakeholder roles and reforms

- To what extent are the various stakeholders executing their roles and mandates? Where are the gaps and how best can these gaps be addressed in a sustainable and responsive manner? Probe for Governments, NGOs, Community like lay responders, Hospitals, partners and policy provisions for these actors]
- Are there any reforms or initiatives happening targeting pre-hospital trauma care across the various stakeholder platforms? What are these initiatives? Which gaps will they address and what will be their intended effect in the health systems and pre-hospital trauma care service delivery?
- What innovations or opportunities in the health systems would allow the various key stakeholder to make positive and meaningful strengthening of health systems for improved pre-hospital trauma outcomes?

d) Overall, Health system

- In your own opinion, what other elements or factors are critical improving the pre-hospital care for major trauma responses and related outcomes?
- In what ways can technology be innovatively used to address challenges and gaps in pre-hospital care? [Probe for concerns, barriers and possible solutions]
- What other out of hospital care approaches, elements and or tools should be incorporated in the health system response to improve its responsiveness and effectiveness to local-context trauma needs and priorities in Kenya? How best can these approach elements be integrated in the broader health system responses?

e) Suggestions

- What are your take home suggestions or comment[s] on improving pre-hospital care outcomes in the context of Kenya?

Appendix 7 Traumatic Brain Injury ICD-10 Codes

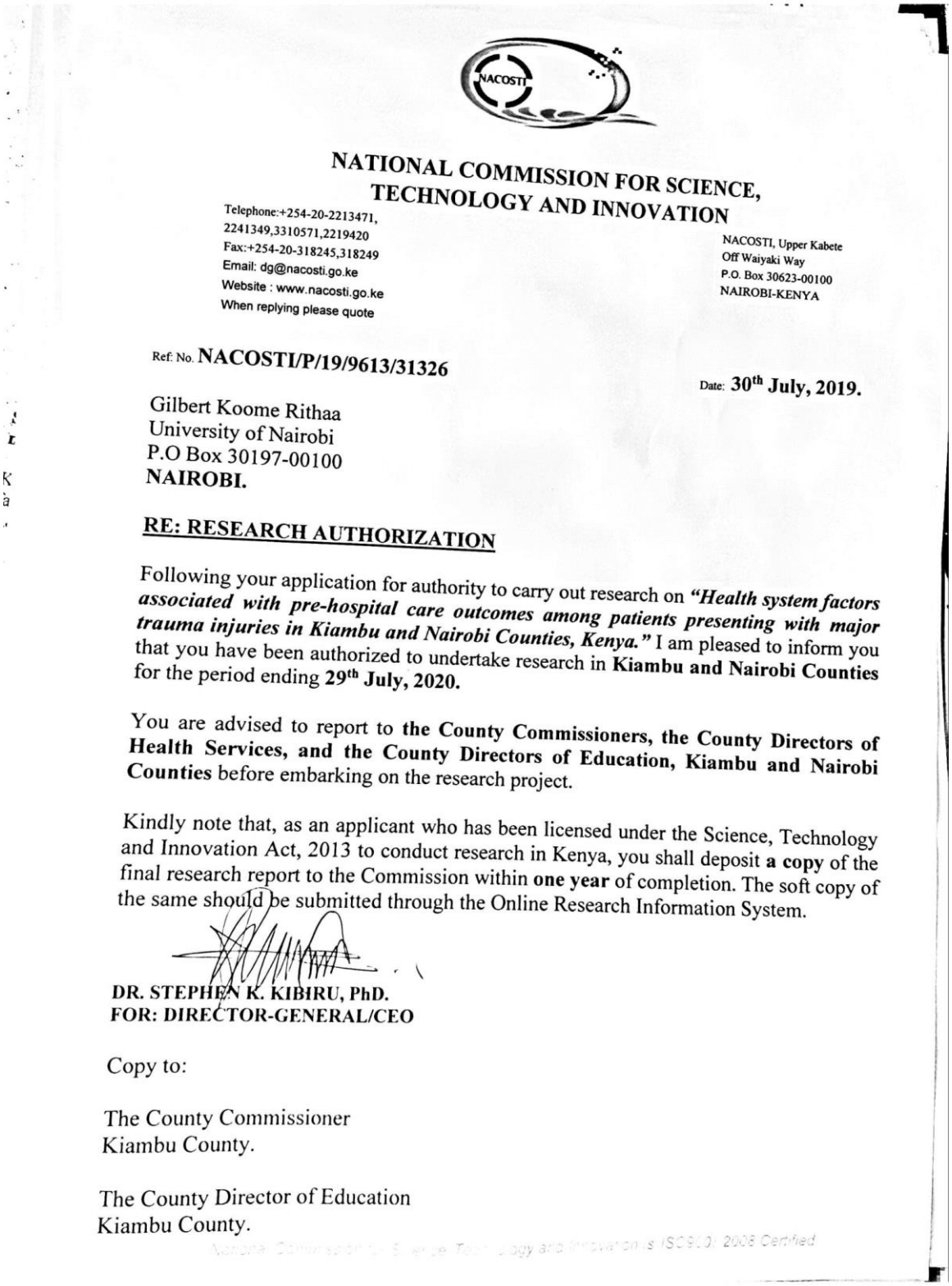
No.	ICD codes	Description
1	S02.0	Fracture of vault of skull
2	S02.1	Fracture of base of skull
3	S02.7-S02.9	Multiple fractures involving skull and facial bones Fractures of other skull and facial bones Fracture of skull and facial bones, part unspecified
4	S04.0-S04.9	Injury of cranial nerves
5	S07.1	Crushing injury of skull
6	S07.8	Crushing injury of other parts of head
7	S07.9	Crushing injury of head, part unspecified
8	S09.7-S09.9	Multiple injuries of head Other specified injuries of head Unspecified injury of head
9	T02.0	Fractures involving head with neck
10	T04.0	Crushing injuries involving head with neck
11	T06.0	Injuries of brain and cranial nerves with injuries of nerves and spinal cord at neck level

Appendix 8 List of Key Informants Interviewed

No	KII Code	Role	Department	Institution
1.	A01	Head	Emergency ser.	St. Johns Ambulance
2.	A01	Ambulance Coordinator	County	Kiambu County
3.	A02	Dispatch coordinator	Emergency ser.	St. Johns Ambulance
4.	A03	Paramedic	Emergency ser.	St. Johns Ambulance
5.	C01	Ambulance Coordinator	County	Kiambu County
6.	C02	Chief of Health	County	Kiambu County
7.	C03	Chief of Health	County	Kiambu County
8.	C04	Ambulance Coordinator	County	Nairobi County
9.	C05	Chief of Health	County	Nairobi County
10.	D01	Head	A&E	KNH
11.	D02	Head	A&E	Kikuyu
12.	D03	Doctor	A&E	Kikuyu
13.	D04	Head	A&E	Malter Hospital
14.	D05	Head	A&E	Thika Level 5
15.	D06	Doctor	A&E	Thika level 5
16.	D07	Doctor	A&E	Kiambu Hospital
17.	D08	Doctor	A&E	Mbagathi Hospital
18.	D09	Head	A&E	Mama Lucy Kibaki
19.	D10	Doctor	A&E	Mama Lucy Kibaki
20.	N01	Referral Coordinator & Nurse	A&E	KNH

No	KII Code	Role	Department	Institution
21.	N02	Nurse	A&E	KNH
22.	N03	Deputy Chief, SACN	A&E	KNH
23.	N04	Deputy Chief, HRIO	A&E	KNH
24.	N05	Nurse	A&E	Kikuyu
25.	N06	Nurse	A&E	Kiambu Hospital
26.	N07	Head, HR	A&E	Malter Hospital
27.	N08	Nurse	A&E	Thika level 5
28.	N09	Head	A&E	Kiambu Hospital
29.	N10	Nurse	A&E	Kiambu Hospital
30.	N11	Head	A&E	Mbagathi Hospital
31.	N12	Nurse	A&E	Mbagathi Hospital
32.	N13	Nurse	A&E	Mama Lucy Kibaki
33.	S01	Chair	ETMA	ETMA
34.	S02	Emergency Unit	Government	Policy
35.	S03	Head	NHIF	Thika Branch
36.	E01	Public Health Policy	Expert	Mount Kenya University
37.	E02	Health Systems Strengthening	Expert	Kenyatta University
38.	E03	Emergency Trauma Care	Expert	Independent Consultant

Appendix 9 Research Permit from NACOSTI



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/19/9613/31326**

Date: **30th July, 2019.**

Gilbert Koome Rithaa
University of Nairobi
P.O Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Health system factors associated with pre-hospital care outcomes among patients presenting with major trauma injuries in Kiambu and Nairobi Counties, Kenya."*** I am pleased to inform you that you have been authorized to undertake research in **Kiambu and Nairobi Counties** for the period ending **29th July, 2020.**

You are advised to report to **the County Commissioners, the County Directors of Health Services, and the County Directors of Education, Kiambu and Nairobi Counties** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kiambu County.

The County Director of Education
Kiambu County.

National Commission for Science, Technology and Innovation is ISO9001: 2008 Certified

Appendix 10 Ethical Approval from KNH-UON ERC

UNIVERSITY OF NAIROBI
COLLEGE OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

APPROVED
06 JUN 2019
KNH/UoN-ERC
P. O. BOX 20723 - 00202 NAIROBI

KNH-UON ERC
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Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/212

6th June, 2019

Rithaa Koome Gilbert
Reg. No. H80/52031/2017
PhD Candidate
School of Public Health
College of Health Sciences
University of Nairobi

Dear Gilbert,

RESEARCH PROPOSAL: HEALTH SYSTEM FACTORS ASSOCIATED WITH PRE-HOSPITAL CARE OUTCOMES AMONG PATIENTS PRESENTING WITH MAJOR TRAUMA INJURIES IN KIAMBU AND NAIROBI COUNTIES, KENYA (P905/12/2018)

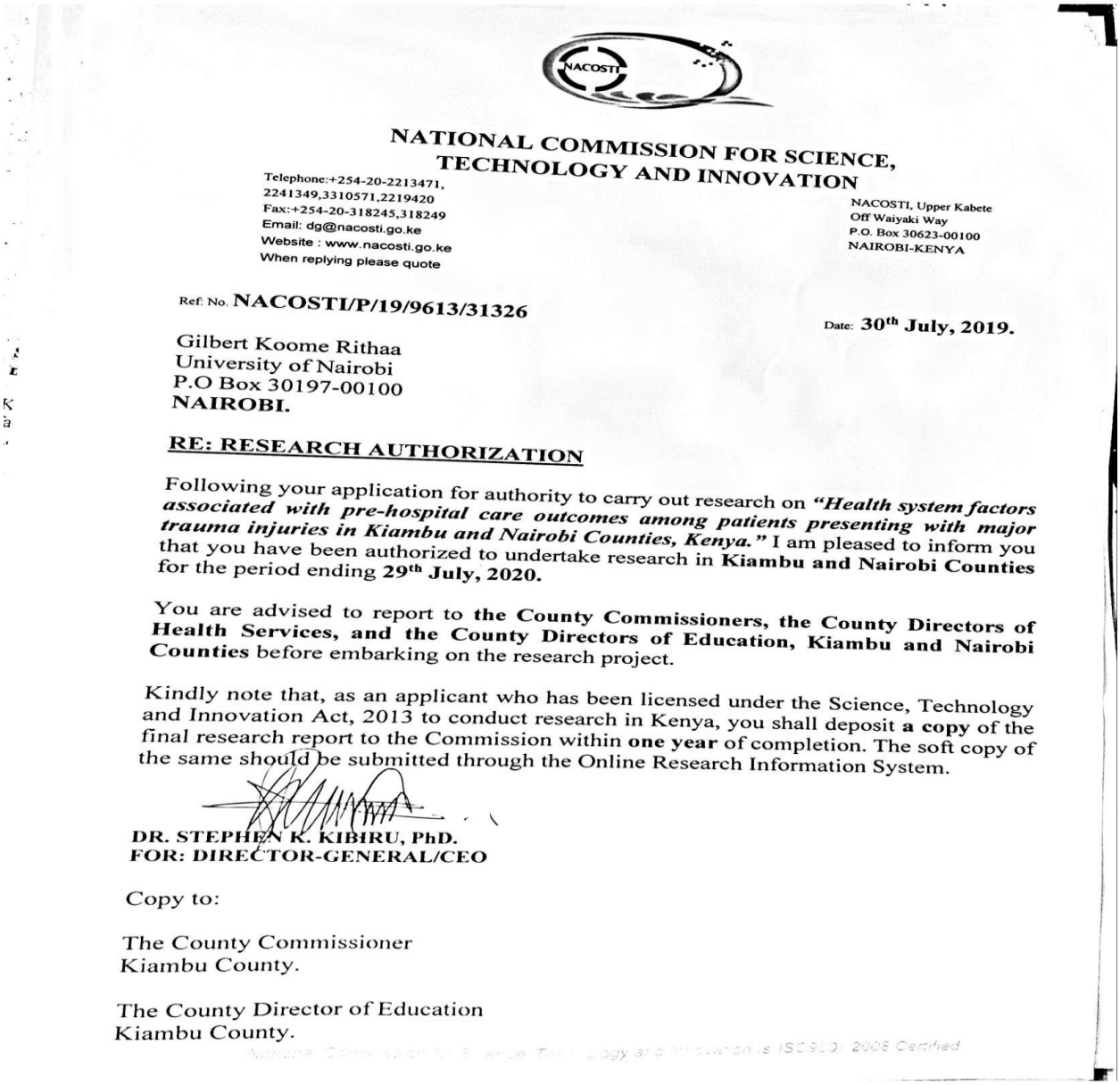
This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and approved your above research proposal. The approval period is 6th June 2019 – 5th June 2020.

This approval is subject to compliance with the following requirements:

a. Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b. All changes (amendments, deviations, violations etc.) are submitted for review and approval by KNH-UoN ERC before implementation.
c. Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
d. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
f. Submission of an *executive summary* report within 90 days upon completion of the study. This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

Protect to discover

Appendix 10 Research Permit from NACOSTI



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/19/9613/31326**

Date: **30th July, 2019.**

Gilbert Koome Rithaa
University of Nairobi
P.O Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

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You are advised to report to **the County Commissioners, the County Directors of Health Services, and the County Directors of Education, Kiambu and Nairobi Counties** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kiambu County.

The County Director of Education
Kiambu County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

Appendix 11 Study Approval from KNH

Email:knhadmin@knh.or.ke
Tel:2726300-9
Fax: 2725272

KENYATTA NATIONAL HOSPITAL
P.O. BOX 20723 – 00202 – KNH
NAIROBI

REF:KNH/A&E-HOD/RES/7/VOL.2 **Date: 30th July 2019**

Mr. Rithaa Koome Gilbert
Reg. No. H80/52031/2017
PhD Candidate
School of Public Health
College of Health Sciences
University of Nairobi

Dear Mr Rithaa,

RE: HEALTH SYSTEM FACTORS ASSOCIATED WITH PRE-HOSPITAL CARE OUTCOMES AMONG PATIENTS PRESENTING WITH MAJOR INJURIES IN KIAMBU AND NAIROBI COUNTIES, KENYA

Following approval of your study by the KNH/UON ERC and completion of the KNH Study registration form, permission is hereby granted for you to distribute questionnaires and interview nurses from the KNH Accident & Emergency to enable you complete your study titled **"Health System Factors associated with pre-hospital care outcomes among patients presenting with major trauma injuries in Kiambu and Nairobi Counties, Kenya".**

Kindly liaise with the Assistant Chief Nurse in charge of Accident & Emergency Department for facilitation. By a copy of this letter, the Research Coordinator, A&E and the SACN In charge, A&E are informed and requested to facilitate.

You will be required to forward a copy of your study report to this office after completion.

KENYATTA NATIONAL HOSPITAL ★ 30 JUL 2019 ★ P. O. Box 20723 - 00202 KNH Accident & Emergency Department

Dr. Alice Maingi
HOD – A&E

c.c.
Research Coordinator – A&E
SACN – A&E

Appendix 12 Study Approval from Malter Hospital

Mater Misericordiae Hospital
Under the Sisters of Mercy

P. O. Box 30325 - 00100
Dunga Road, Nairobi, Kenya
Telephone: (254) (020) 6903000
Mobile Lines: 0719 - 073000, 0732 - 163000
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Email:inform@materkenya.com
Website: www.materkenya.com

9th October 2019

Our Ref: MMH/DMS/VOL.2019/035

Rithaa Koome Gilbert,
P.O Box 5306-00200,
Nairobi.

Dear Gilbert,

RE: PERMISSION TO CONDUCT A STUDY ON HEALTH SYSTEM FACTORS ASSOCIATED WITH PRE-HOSPITAL CARE OUTCOMES AMONG PATIENTS PRESENTING WITH MAJOR TRAUMA INJURIES IN KIAMBU AND NAIROBI COUNTIES, KENYA

We acknowledge receipt of your request for permission and assistance to conduct a research study on 'Health System Factors associated with Pre-hospital Care Outcomes among patients presenting with Major Trauma Injuries in Kiambu and Nairobi Counties, Kenya.'

Standards & Ethics Sub-Committee of The Mater Misericordiae Hospital, has reviewed your request as entitled above, and found it acceptable.

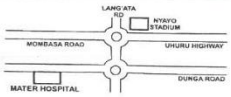
You are hereby allowed to proceed with your research but **MUST** submit a copy of proposal and findings for inclusion in our inventory.

I wish you well.

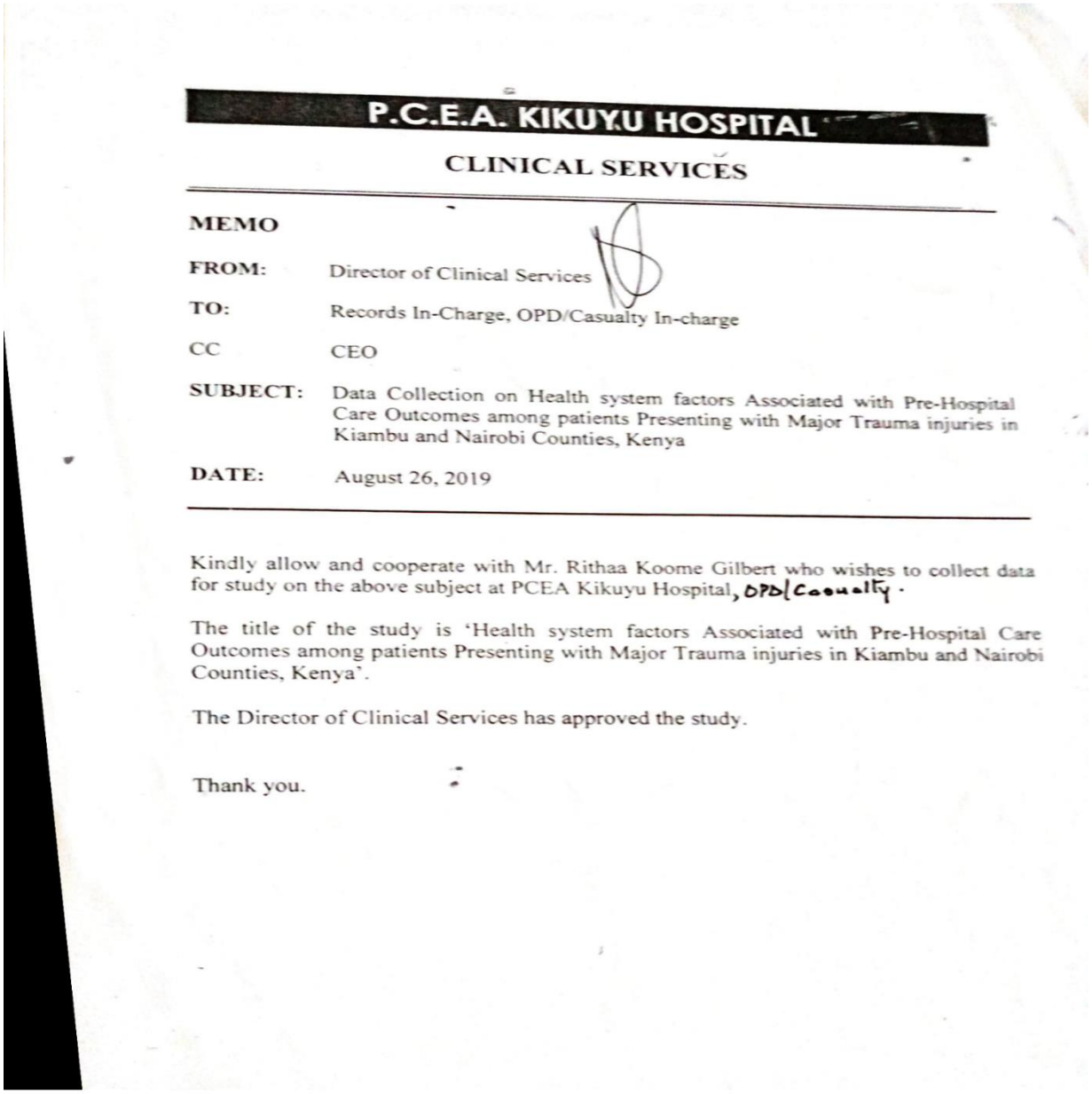
Thank you.

Yours Faithfully,
FOR: THE MATER MISERICORDIAE HOSPITAL

Dr. Andrew Ndonga
CHAIR, STANDARDS AND ETHICS SUB COMMITTEE



Appendix 13 Study Approval from Kikuyu Hospital



P.C.E.A. KIKUYU HOSPITAL

CLINICAL SERVICES

MEMO

FROM: Director of Clinical Services

TO: Records In-Charge, OPD/Casualty In-charge

CC CEO

SUBJECT: Data Collection on Health system factors Associated with Pre-Hospital Care Outcomes among patients Presenting with Major Trauma injuries in Kiambu and Nairobi Counties, Kenya

DATE: August 26, 2019

Kindly allow and cooperate with Mr. Rithaa Koome Gilbert who wishes to collect data for study on the above subject at PCEA Kikuyu Hospital, OPD/Casualty.

The title of the study is 'Health system factors Associated with Pre-Hospital Care Outcomes among patients Presenting with Major Trauma injuries in Kiambu and Nairobi Counties, Kenya'.

The Director of Clinical Services has approved the study.

Thank you.

Appendix 14 Study Authorization from Nairobi County

NAIROBI CITY COUNTY

Telephone 020 344194

web: www.nairobi.go.ke

City Hall,
P. O. Box 30075-00100,
Nairobi,
KENYA.

COUNTY HEALTH SERVICES

REF: CHS/1/13/ (13) - 019

GILBERT KOOME RITHAA
UNIVERSITY OF NAIROBI (UON)
P.O BOX 5306 - 0010
NAIROBI.

DATE: 30th SEPTEMBER, 2019

RE: RESEARCH AUTHORIZATION

Reference is made to a letter from the Director Human Resource Management

Ref. NCC/HRD/HRM/10/1434/MWN/2019 dated 30th September, 2019.

Authority is hereby granted to you to carry a research on **"Health system factors associated with pre – hospital care outcomes among patients presenting with major traumer injuries in Nairobi County"** at MLKH, MBAGATHI, AMBULANCE SERVICES".

Please note that the pre-testing of research tools run for a period One (1) Month w.e.f 1st October, 2019 to 29th November, 2019.

During the course of your pre-testing, you will be expected to adhere to the rules and regulations governing the Nairobi City County.

During your pre-testing there will be no costs devolving on the County.

That you undertake to indemnify the County against any claims that may arise from your pre-testing.

By a copy of this letter, the Medical Superintendents of MLKH, MBAGATHI and IN CHARGE AMBULANCE SERVICES are requested to accord you the necessary assistance.

ADMINISTRATIVE OFFICER

LILIAN SHIKANDA
FOR: CHIEF ADMINISTRATIVE OFFICER – (CHS)

CC: Medical Superintendent – MLKH, MBAGATHI
IN CHARGE – AMBULANCE SERVICES

Appendix 15 Study Authorization from Kiambu County

COUNTY GOVERNMENT OF KIAMBU
DEPARTMENT OF HEALTH SERVICES

All correspondence should be addressed to
HEAD HRDU – HEALTH DEPARTMENT
Email address: mndiritu@gmail.com
mkwasa@live.com
Mobile: 0721641516
0721974633

HEALTH RESEARCH AND DEVELOPMENT UNIT
P. O. BOX 2344 – 00900
KIAMBU

Ref. No: KIAMBU/HRDU/AUTHO/2019/09/30/Koome GR

Date: 30 Sep 2019

TO WHOM IT MAY CONCERN,

RE: CLEARANCE TO CONDUCT RESEARCH IN KIAMBU COUNTY

Kindly note that we have received a request by **Mr. Gilbert Rithaa Koome** of **University Of Nairobi** to carry out research in Kiambu County, the research topic being on ***"Health System Factors Associated With Pre-Hospital Care Outcomes Among Patients Presenting With Major Trauma Injuries In Kiambu And Nairobi Counties, Kenya"***.

We have duly inspected his documents and found that he has been cleared by **Kenyatta National Hospital - University Of Nairobi Ethical Review Committee** until **05 Jun 2020**. He thus does not need any further clearance with another regulatory body in order to conduct research within the county of Kiambu.

However, it is incumbent upon the facility in which the research is being carried out to ensure that they are conversant with the remit of the study and operate in line with their institutional norms on conducting research. This note also accords him the duty to provide feedback on his research to the county at the conclusion of his research.

DR. M. NDIRITU NDIRANGU
COUNTY HEALTH RESEARCH DEVELOPMENT UNIT
KIAMBU COUNTY

Appendix 16 Field Team Training Schedule

Date: July 30th-August 2nd 2019 Hotel Thika		**Venue:** Enden
Time	**Lesson**	**Facilitator**
Day One: July 30, 2019		
9.00 am-9: 15 am	Introduction/Ice break	Gilbert
9:15 am- 10:15 am	Study Overview: Background, Objectives and Anticipated Outcomes	Gilbert
10:15 am- 10:30 am	**Tea Break**	**All**
10:30 am- 11:30 am	Study methods: Data Collection Methods and processes	Gilbert
11:30 am – 12: 30 pm	Role Play session	Gilbert
12:30 pm- 1:30 pm	**Lunch**	**All**
1:30 am- 2:30 pm	Study Methods: Sampling processes and Procedures	Gilbert & Dr. Dennis
2:30 pm- 3:30 pm	Role play session	Gilbert & Dr. Dennis
3:30pm-4:30pm	Discussion and feedback	Gilbert & Dr. Dennis
4:30 pm- 4:45 pm	**Tea Break**	**All**
Day Two: July 31, 2019		
9.00 am-9: 15 am	Prayers and Recap	Gilbert

Date: July 30th-August 2nd 2019 Hotel Thika		**Venue:** Enden
Time	**Lesson**	**Facilitator**
9:15 am- 10:15 am	Informed Consent Procedures	Gilbert
10:15 am- 10:30 am	**Tea Break**	**All**
10:30 am- 11:30 am	Role Play Session	Gilbert
11:30 am – 12: 30 pm	Review of data tools	Gilbert
12:30 pm- 1:30 pm	**Lunch and Prayers**	**All**
1:30 am- 2:30 pm	Review of data tools	Gilbert
2:30 pm- 3:30 pm	Data Abstraction tips	Dr. Dennis
3:30 pm- 4:30 pm	Questions and Answer session	Khamar and Gilbert
4:30 pm- 4:45 pm	**Tea Break**	**All**
Day Three: August 1, 2019		
9.00 am-9: 15 am	Prayers and Recap	Gilbert
9:15 am- 10:15 am	Interview Skills and Tips	Gilbert
10:15 am- 10:30 am	**Tea Break**	**All**
10:30 am- 11:30 am	Ethical, logistic and security issue management	Gilbert
11:30 am – 12: 30 pm	Role Plays	Gilbert
12:30 pm- 1:30 pm	**Lunch**	**All**
1:30 am- 2:30 pm	Introduction to mobile data application for data collection and management	Gilbert

Date: July 30th-August 2nd 2019 Hotel Thika		**Venue:** Enden
Time	**Lesson**	**Facilitator**
2:30 pm- 3:30 pm	Conduct dummy interviews	Gilbert
3:30pm-4:30pm	Feedback session	Gilbert
4:30 pm- 4:45 pm	**Tea Break**	**All**
Day Four: August 2, 2019		
9.00 am-9: 30 am	Prayers, Recap and Instructions	Gilbert
9:30 am- 10:15 am	Pre-test	Gilbert & Dr. Dennis
10:15 am- 10:30 am	**Tea Break**	**All**
10:30 am- 11:30 am	Observed Pre-test	Gilbert & Dr. Dennis
11:30 am – 12: 30 pm	Observed Pre-test	Gilbert & Dr. Dennis
12:30 pm- 1:30 pm	**Lunch**	**All**
1:30 am- 2:30 pm	Discussions and Feedback	Gilbert & Dr. Dennis
2:30 pm- 3:30 pm	Discussions and Feedback	Gilbert & Dr. Dennis
3:30pm-4:30pm	Field Plan Logistics	Gilbert
4:30 pm- 4:45 pm	**Tea Break**	**All**

Appendix 17 Mantel-Hansel [M-H] Analysis Supplementary Tables

Study Variables		Patient Status		Total	M-H Statistics	Common OR	95% CI	
		Alive	Dead				Lower	Upper
Age	18-29 years	71(53%)	64(47%)	135(43%)	p=0.737	0.894	0.553	1.445
	30-39 years	46(48%)	49(52%)	95(30%)	p=0.940	1.055	0.633	1.759
	40-49 years	17(45%)	21(55%)	38(12%)	p=0.462	1.464	0.669	3.203
	50-59 years	14(54%)	12(46%)	26(08%)	p=0.863	0.842	0.356	1.992
	60+ years	10(45%)	12(55%)	22(07%)	p=0.982	0.905	0.361	2.27
Gender	Male	139(52%)	129(48%)	268(85%)	p=0.072	1.927	0.988	3.76
	Female	19(40%)	29(60%)	48(15%)				
Comorbidity	Comorbid	101(52%)	92(48%)	193(61%)	p=0.344	1.303	0.795	2.137
	Not comorbid	57(46%)	66(54%)	123(39%)				
Blood Pressure	Normal	63(47%)	72(53%)	135(43%)	p=0.363	1.303	0.791	2.147

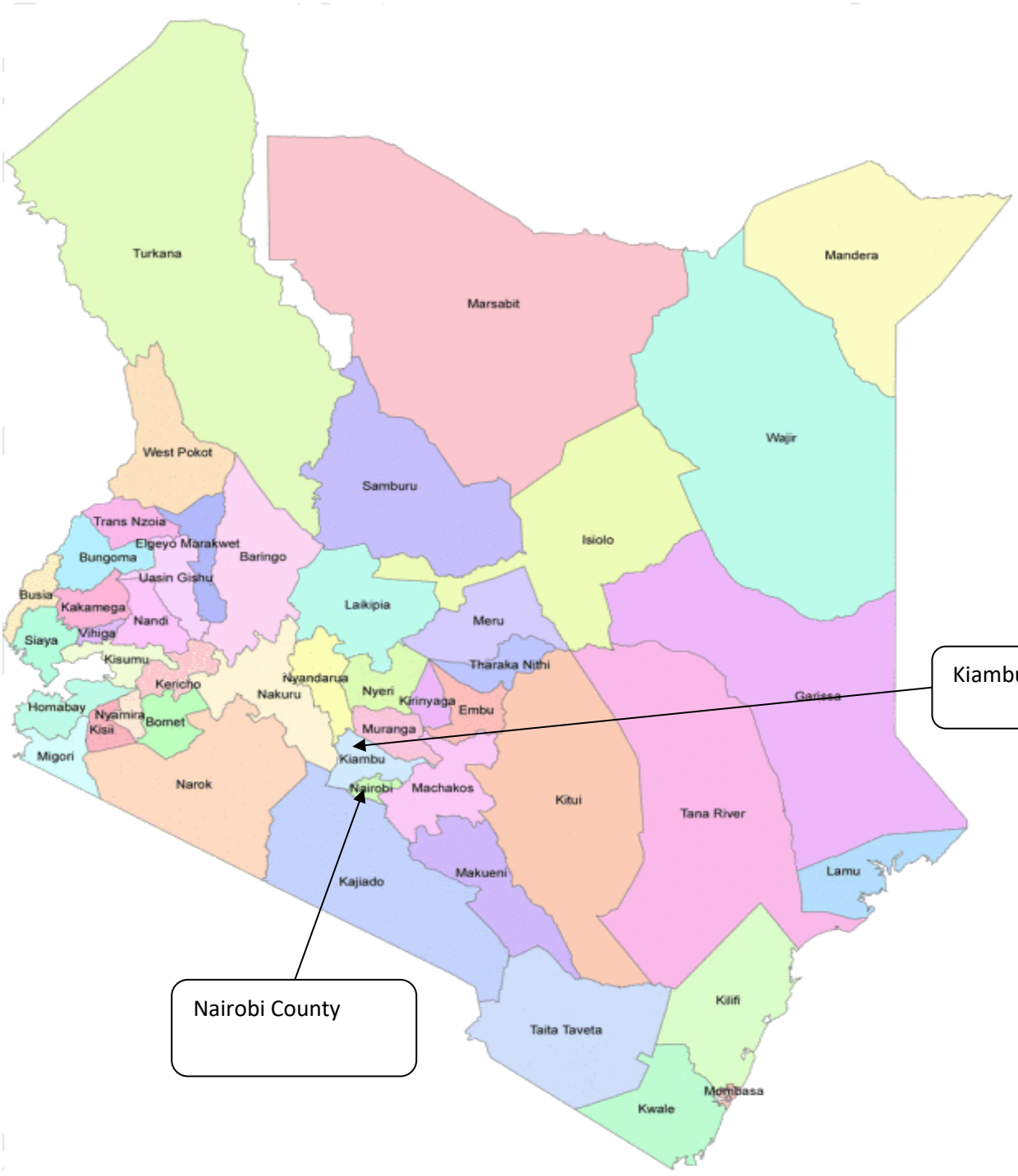
Study Variables		Patient Status		Total	M-H Statistics	Common OR	95% CI	
		Alive	Dead				Lower	Upper
	Elevated	36(60%)	24(40%)	60(19%)	p=0.112	0.582	0.313	1.084
	Hypertension	55(45%)	66(55%)	121(38%)	p=0.317	1.328	0.807	2.185
Trauma Severity [GCS]	Severe	54(35%)	100(65%)	154(49%)	p=0.001	2.955	1.847	4.726
	Moderate	37(56%)	29(44%)	66(21%)	p=0.164	0.651	0.374	1.135
	Mild	67(70%)	29(30%)	96(30%)	p=0.001	0.382	0.227	0.643
Presence of Hypoxemia	Not Hypoxemic	119(55%)	98(45%)	217(69%)	p=0.104	1.57	0.941	2.628
	Hypoxemic	39(39%)	60(61%)	99(31%)				
Patient Consciousness	Conscious	95(42%)	130(58%)	225(71%)	p=0.025	2.046	1.129	3.707
	Unconscious	63(69%)	28(31%)	91(29%)				
Triage Status	Not urgent	34(42%)	47(58%)	81(26%)	p=0.004	2.488	1.350	4.587
	Urgent	50(52%)	47(48%)	97(31%)	p=0.413	0.774	0.458	1.308

Study Variables		Patient Status		Total	M-H Statistics	Common OR	95% CI	
		Alive	Dead				Lower	Upper
	Very urgent	74(54%)	64(46%)	138(44%)	p=0.112	0.647	0.391	1.068
Trauma Patterns								
Trauma Mechanism	RTA	78(42%)	106(58%)	184(58%)	p=0.003	2.099	1.288	3.421
	Gun shots	11(69%)	5(31%)	16(5%)	p=0.454	0.417	0.097	1.783
	Violence	46(56%)	36(44%)	82(26%)	p=0.313	0.731	0.423	1.263
	Falls	35(60%)	23(40%)	58(18%)	p=0.092	0.538	0.282	1.027
RTA category	Motor vehicle	49(43%)	64(57%)	113(61%)	p=0.571	1.302	0.647	2.62
	Motorcycle	29(41%)	42(59%)	71(39%)				
Type of RTA casualty	Passenger	10(43%)	13(57%)	23(18%)	p=0.877	1.043	0.399	2.73
	Pedestrian	18(49%)	19(51%)	37(28%)	p=0.32	0.587	0.250	1.38
	Motorist/cyclist	28(40%)	42(60%)	70(54%)	p=0.747	1.186	0.603	2.334

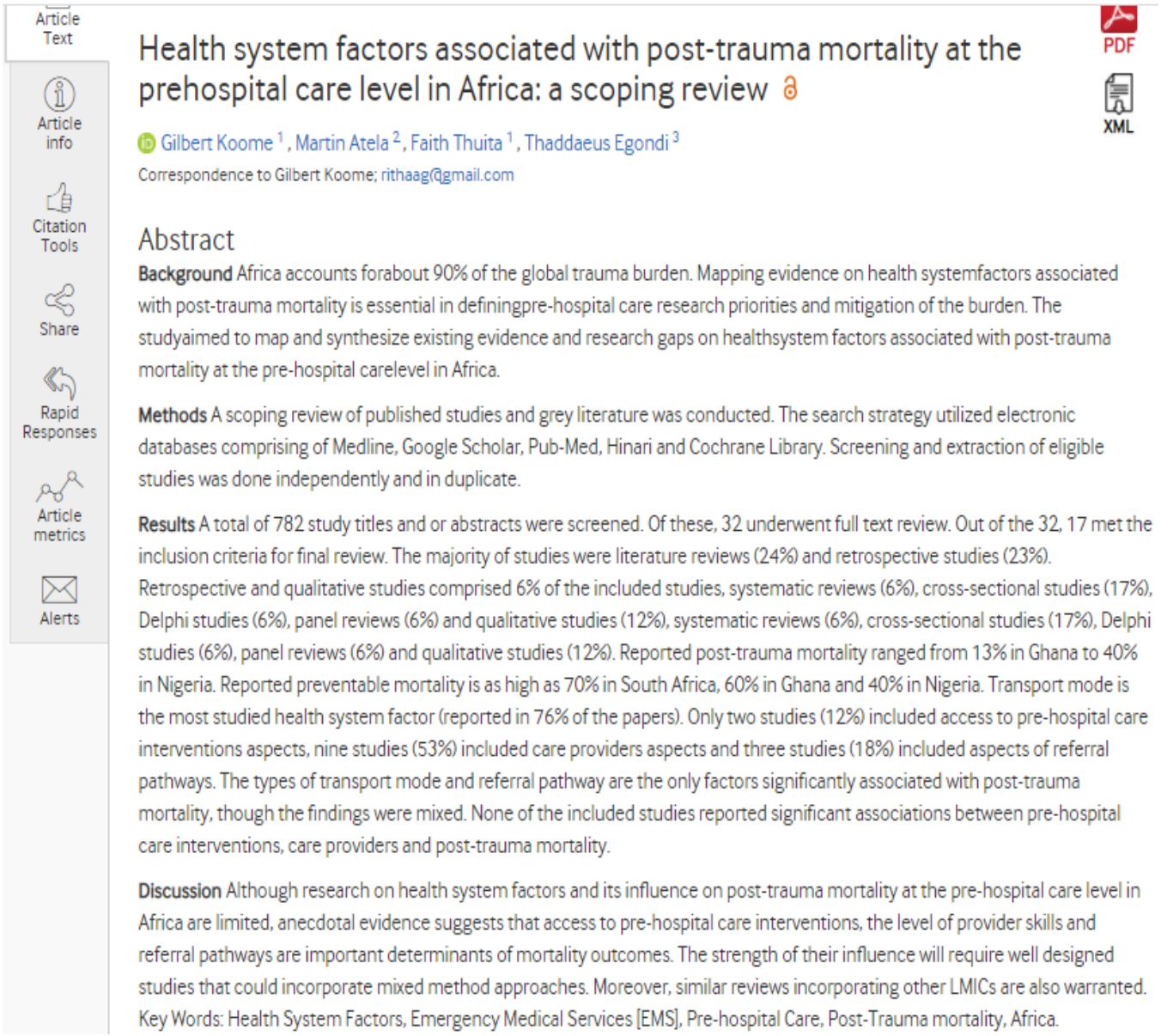
Study Variables		Patient Status		Total	M-H Statistics	Common OR	95% CI	
		Alive	Dead				Lower	Upper
Type of Injury	Penetrating Injury	55(60%)	36(40%)	91(29%)	p=0.069	1.691	0.993	2.878
	Blunt Injury	103(46%)	122(54%)	225(71%)				
Day of Injury	Weekend							
	Weekday							
Type of pre-hospital Care	ALS	23(41%)	33(59%)	56(18%)	p=0.3434	1.439	0.752	2.752
	BLS	36(47%)	41(53%)	77(24%)	p=0.486	0.773	0.424	1.408
	Lay responder care	99(54%)	84(46%)	183(58%)	p=0.983	0.958	0.563	1.632
Enroute Patient Monitoring	No patient observation	129(50%)	129(50%)	258(82%)	p=0.229	1.619	0.813	3.226
	Patient Observation	29(50%)	29(50%)	58(18%)				
Type of care provider	Paramedic	29(50%)	29(50%)	58(18%)	p=0.229	0.618	0.31	1.23
	Nurse	30(37%)	51(63%)	81(26%)	p=0.033	1.925	1.083	3.421
	Lay responder	99(56%)	78(44%)	177(56%)	p=0.349	0.745	0.434	1.28

Study Variables		Patient Status		Total	M-H Statistics	Common OR	95% CI	
		Alive	Dead				Lower	Upper
Lay responder care Approach	Lay responder only	101(57%)	77(43%)	178(66%)	p=0.032	2.027	1.103	3.724
	Hybrid-Lay Responder	32(35%)	60(65%)	92(34%)				
Type of Transport Mode	Ambulance	58(42%)	79(58%)	137(43%)	p=0.346	0.741	0.428	1.282
	Non ambulance	100(56%)	79(44%)	179(57%)				
Type of ambulance ownership	Private/NGO	29(50%)	29(50%)	58(42%)	p=0.0457	2.503	1.088	5.759
	Public	29(37%)	50(63%)	79(58%)				
Referral Pathway	Direct referral	128(54%)	107(46%)	235(74%)	p=0.033	1.925	1.083	3.421
	Indirect referral	30(37%)	51(63%)	81(26%)				
	KNH [Public]	67(40%)	100(60%)	167(53%)	p=0.0303	2.09	1.307	3.344
Type of Trauma Care Facility	Malter Hospital [Private]	36(75%)	12(25%)	48(15%)	p=0.010	0.366	0.176	0.761
	Kikuyu Hospital [Mission]	55(54%)	46(46%)	101(32%)	p=0.032	0.736	0.455	1.192

Appendix 18 Map of Kenya showing Kiambu and Nairobi Counties



Appendix 19 Published Study and link – Scoping Review Paper



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Health system factors associated with post-trauma mortality at the prehospital care level in Africa: a scoping review

Gilbert Koome [1], Martin Atela [2], Faith Thuita [1], Thaddaeus Egondi [3]

Correspondence to Gilbert Koome; rithaag@gmail.com

Abstract

Background Africa accounts forabout 90% of the global trauma burden. Mapping evidence on health systemfactors associated with post-trauma mortality is essential in definingpre-hospital care research priorities and mitigation of the burden. The studyaimed to map and synthesize existing evidence and research gaps on healthsystem factors associated with post-trauma mortality at the pre-hospital carelevel in Africa.

Methods A scoping review of published studies and grey literature was conducted. The search strategy utilized electronic databases comprising of Medline, Google Scholar, Pub-Med, Hinari and Cochrane Library. Screening and extraction of eligible studies was done independently and in duplicate.

Results A total of 782 study titles and or abstracts were screened. Of these, 32 underwent full text review. Out of the 32, 17 met the inclusion criteria for final review. The majority of studies were literature reviews (24%) and retrospective studies (23%). Retrospective and qualitative studies comprised 6% of the included studies, systematic reviews (6%), cross-sectional studies (17%), Delphi studies (6%), panel reviews (6%) and qualitative studies (12%), systematic reviews (6%), cross-sectional studies (17%), Delphi studies (6%), panel reviews (6%) and qualitative studies (12%). Reported post-trauma mortality ranged from 13% in Ghana to 40% in Nigeria. Reported preventable mortality is as high as 70% in South Africa, 60% in Ghana and 40% in Nigeria. Transport mode is the most studied health system factor (reported in 76% of the papers). Only two studies (12%) included access to pre-hospital care interventions aspects, nine studies (53%) included care providers aspects and three studies (18%) included aspects of referral pathways. The types of transport mode and referral pathway are the only factors significantly associated with post-trauma mortality, though the findings were mixed. None of the included studies reported significant associations between pre-hospital care interventions, care providers and post-trauma mortality.

Discussion Although research on health system factors and its influence on post-trauma mortality at the pre-hospital care level in Africa are limited, anecdotal evidence suggests that access to pre-hospital care interventions, the level of provider skills and referral pathways are important determinants of mortality outcomes. The strength of their influence will require well designed studies that could incorporate mixed method approaches. Moreover, similar reviews incorporating other LMICs are also warranted.

Key Words: Health System Factors, Emergency Medical Services [EMS], Pre-hospital Care, Post-Trauma mortality, Africa.

Appendix 20 Published Study abstract and link – Trauma Patterns

RESEARCH ARTICLE

Check for updates

REVISED Association between traumatic brain injury (TBI) patterns and mortality: a retrospective case-control study [version 2; peer review: 2 approved]

Gilbert Koome [1], Faith Thuita[1], Thaddaeus Egondi[2], Martin Atela [3]

Author details

ALL METRICS

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Abstract

Background: Low and medium income countries (LMICs) such as Kenya experience nearly three times more cases of traumatic brain injury (TBI) compared to high income countries (HICs). This is primarily exacerbated by weak health systems especially at the pre-hospital care level. Generating local empirical evidence on TBI patterns and its influence on patient mortality outcomes is fundamental in informing the design of trauma-specific emergency medical service (EMS) interventions at the pre-hospital care level. This study determines the influence of TBI patterns and mortality.

Methods: This was a case-control study with a sample of 316 TBI patients. Data was abstracted from medical records for the period of January 2017 to March 2019 in three tertiary trauma care facilities in Kenya. Logistic regression was used to assess influence of trauma patterns on TBI mortality, controlling for patient characteristics and other potential confounders.

Results: The majority of patients were aged below 40 years (73%) and were male (85%). Road traffic injuries (RTIs) comprised 58% of all forms of trauma. Blunt trauma comprised 71% of the injuries. Trauma mechanism was the only trauma pattern significantly associated with TBI mortality. The risk of dying for patients sustaining RTIs was 2.83 times more likely compared to non-RTI patients [odds ratio (OR) 2.83, 95% confidence interval (CI) 1.62-4.93, p=0.001]. The type of transfer to hospital was also significantly associated with mortality outcome, with a public hospital having a two times higher risk of death compared to a private hospital [OR 2.18 95%CI 1.21-3.94, p<0.009].

Conclusion: Trauma mechanism (RTI vs non-RTI) and type of tertiary facility patients are transferred to (public vs private) are key factors influencing TBI mortality burden. Strengthening local EMS trauma response systems targeting RTIs augmented by adequately resourced and equipped public facilities to provide quality lifesaving interventions can reduce the burden of TBIs.

Keywords

Trauma Patterns, Patient Characteristics, pre-hospital Care, Traumatic Brain Injuries, Trauma mortality

Appendix 21 Consent to Audio Recording and Transcription

Study Title: *(*Association between health system factors at the prehospital level and traumatic brain injury (TBI) mortality in Kiambu and Nairobi counties, Kenya

Researcher's Name: Gilbert Koome Rithaa,

Affiliation: School of Public Health, University of Nairobi

Email: rithaag@gmail.com

This study involves the audio or video recording of your interview with the researcher. Neither your name nor any other identifying information will be associated with the audio or audio recording or the transcript. Only the research team will be able to listen (view) to the recordings.

The tapes will be transcribed by the researcher and erased once the transcriptions are checked for accuracy. Transcripts of your interview may be reproduced in whole or in part for use in presentations or written products that result from this study. Neither your name nor any other identifying information (such as your voice or picture) will be used in presentations or in written products resulting from the study.

By signing this form, I am allowing the researcher to audio or video tape me as part of this research. I also understand that this consent for recording is effective until the following date: _____.

On or before that date, the tapes will be destroyed.

Participant's Signature: _____Date: _____