Epidemiology, Management, and Functional Outcomes of Traumatic Brain Injury in Sub-Saharan Africa

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■ BACKGROUND: **Trauma accounts for 4.7 million deaths each year, with an estimated 90% of these occurring in low- and middle-income countries (LMICs). Approximately half of trauma-related deaths are caused by central nervous system injury. Because a thorough understanding of traumatic brain injury (TBI) in LMICs is essential to mitigate TBI-related mortality, we established a clinical and radiographic database to characterize TBI in our low-income setting.**

■ METHODS: **This is a review of prospectively collected data from Kamuzu Central Hospital, a tertiary care center in the capital of Malawi. All patients admitted from October 2016 through May 2017 with a history of head trauma, altered consciousness, and/or radiographic evidence TBI were included. We performed descriptive statistics, a Cox regression analysis, and a survival analysis.**

■ RESULTS: **There were 280 patients who met inclusion criteria; of these, 80.5% were men. The mean age was 28.8 ± 16.3 years. Median Glasgow Coma Scale (GCS) score was 12 (interquartile range, 8–15). Road traffic crashes constituted the most common injury mechanism (60.7%). There were 148 (52.3%) patients who received a computed tomography scan, with the most common findings being contusions (26.1%). Of the patients, 88 (33.0%) had severe TBI, defined as a GCS score ≤8, of whom 27.6% were intubated and 10.3% received tracheostomies. Overall mortality was 30.9%. Of patients who survived, 80.1% made a good recovery. Female sex was protective, and the only significant predictor of poor functional outcome was presence of severe TBI (hazard ratio, 2.98; 95% confidence interval, 1.79–4.95).**

■ CONCLUSIONS: **TBI represents a significant part of the global neurosurgical burden of disease. Implementation of proven in-hospital interventions for these patients is critical to attenuate TBI-related morbidity and mortality.**

Key words
- Functional outcomes
- Low-income settings
- Trauma
- Traumatic brain injury

Abbreviations and Acronyms
CT: Computed tomography
GCS: Glasgow Coma Scale
GOS: Glasgow Outcome Scale
ICP: Intracranial pressure
ICU: Intensive care unit
KCH: Kamuzu Central Hospital
LMIC: Low- and middle-income country
TBI: Traumatic brain injury

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INTRODUCTION

Globally, trauma is a significant cause of morbidity and mortality, with more than 4.7 million deaths and approximately 40–50 million disabled after injury annually.[1] Traumatic brain injury (TBI) is the most important single injury contributing to traumatic mortality and morbidity. Injury as a whole, and TBI in particular, is expected to become a leading cause of global morbidity and mortality by the year 2020.

In low- and middle-income countries (LMICs), where an estimated 90% of all trauma-related deaths occur,[2] data suggest that up to half of all trauma-related mortality can be attributed to injury to the central nervous system.[3] The odds of mortality in patients with TBI in LMICs, including sub-Saharan Africa, are more than twice as high as patients in high-income countries.[4] TBI incidence ranges between 150 and 316 cases per 100,000 inhabitants per year in LMICs.[5] The increasing incidence of TBI deaths is caused by a combination of urbanization, a growing middle class, the availability of cheaper cars and motorcycles, and a growing and aging population in the absence of a mature health care system. The effects of TBI are not limited to an individual's health but are also a cause of increased socioeconomic burden.[6]

There is little information on TBI in Africa to inform necessary public health policy, and resource-appropriate clinical management to help reduce TBI-related mortality and morbidity burden. We therefore established a TBI database at our tertiary care center in Malawi to better characterize the presentation, management, and functional outcomes after TBI in our low-resource setting.

METHODS

This is a retrospective review of prospectively collected data from Kamuzu Central Hospital (KCH). All admitted patients who presented from October 2016 through May 2017 with a history of head trauma and associated altered level of consciousness or radiographic evidence of TBI were included. Patients who were brought in dead, or treated and discharged from the emergency department, were excluded, as were patients who had head trauma but no loss of consciousness, a decrease in their Glasgow Come Scale (GCS) score, or had no radiographic evidence of TBI. Because of the retrospective nature of the study, patient consent was not obtained.

Variables collected included demographics, mechanism of injury, and vital signs. Clinical variables such as GCS score, pupillary examination, and focal neurologic findings were captured at admission and again at 24 hours after presentation. Radiographic findings and surgical interventions were recorded as they occurred throughout the hospital stay. The patient's Glasgow Outcome Scale (GOS) score, as determined by the staff neurosurgeon, was recorded at the time of patient disposition (death/discharge/transfer/absconded).

Analyses performed include descriptive statistics of the population and a bivariate analysis in which patients were stratified according to favorable versus poor outcome, with favorable outcome being defined as good recovery or moderate disability per the GOS score, and poor outcome being defined as severe disability, vegetative state, or death. Statistical significance of differences between groups was assessed using Pearson χ^2 test for categorical variables, analysis of variance for continuous variables, and Mann-Whitney rank-sum test for ordinal variables. Cox proportional hazards modeling and a survival time analysis, defining failure as either death or poor functional outcome (severe disability or vegetative state), were performed. Survival analysis was based on time of injury to time of discharge disposition. All analyses were performed using Stata/IC 14.1 (StataCorp, College Station, Texas, USA). The University of North Carolina Institutional Review Board and the National Health Science Review Committee of Malawi approved this study.

Setting

Malawi is a land-locked country in southeastern Africa with a population of 18.6 million people, with a life expectancy of 61.2 years and a gross domestic product of $493 per capita.[7] KCH is a 1000-bed tertiary care center, located in Lilongwe, the capital city, and serving a catchment of 6 million people in central Malawi. KCH has a general surgery residency and a staff of surgical consultants, including general and orthopedic surgeons, and urologists, a pediatric surgeon, and 1 neurosurgeon. Operating theaters are available, but operational capacity is limited by the availability of nursing and anesthetic staff. Basic laboratory investigations are available, as are x-rays, ultrasounds, and a computed tomography (CT) scanner.

RESULTS

During the 8-month study period, 280 patients were admitted to KCH with a primary diagnosis of TBI (Table 1). Based on data

Table 1. Traumatic Brain Injury Patient Characteristics (N = 280)

Patient Characteristics	Value
Age, mean ± SD (years)	28.8 ± 16.3
Male sex	215 (80.5)
Injury etiology	
RTI	162 (60.7)
Assault	66 (24.7)
Fall	27 (10.1)
Other	12 (4.5)
Median time from injury to presentation at KCH (median, IQR) (days)	0 (0—1)
Transferred in	160 (60.4)
Admission GCS eye score (median, IQR)	3 (1—4)
Admission GCS verbal score (median, IQR)	4 (2—5)
Admission GCS motor score (median, IQR)	5 (4—6)
Admission GCS total score (median, IQR)	12 (8—15)
Neurologic signs and symptoms	
Retrograde amnesia	11 (3.9)
Weakness or paralysis	28 (10.0)
Numbness	5 (1.8)
Ataxia	9 (3.2)
Aphasia	18 (6.4)
Seizures	27 (9.6)
Right pupil abnormal	167 (62.5)
Left pupil abnormal	160 (60.4)
Pupils asymmetrical	64 (24.6)
Associated spinal injury	9 (3.2)
Associated injury to chest, abdomen, and extremities	108 (40.4)
Disposition from casualty	
Admitted to ward	179 (67.6)
Admitted to HDU	25 (9.4)
Admitted to ICU	21 (7.9)
Straight to theater	6 (2.3)
Died in casualty	34 (12.8)

Values are number of patients (%) or as otherwise indicated.
KCH, Kamuzu Central Hospital; IQR, interquartile range; GCS, Glasgow Coma Scale; HDU, high-dependency unit; ICU, intensive care unit; RTI, road traffic injury.

from the KCH trauma database[8] from 2009 to 2015, the mean number of trauma patients admitted to KCH per month is 192 patients. Given our 8-month time frame, approximately 1542 trauma patients were admitted during the study period, with TBI patients comprising 280, or 18.2% of all admitted trauma patients. Most patients were men (n = 215, 80.5%), with a mean age of 28.8 ± 16.3 years. Road traffic injury was the most common etiology of TBI (n = 162, 60.7%), followed by assault (n = 66, 24.7%), falls (n = 27, 10.1%), and all other etiologies (n = 11, 4.1%). Most patients (n = 169, 60.4%) were transferred to KCH after presenting to the nearest district hospital, and the mean time between injury and presentation to KCH was 1.6 ± 6.6 days.

Clinical Findings

At admission, the median GCS score was 12 (interquartile range, 8—15). Mild TBI, defined as a GCS score of 13—15, was seen in 116 patients (43.5%), moderate TBI, defined as a GCS score of 9—12, was seen in 65 patients (24.3%), and severe TBI with a GCS score ≤8, was seen in 88 patients (33.0%). Sixty-four patients (24.6%) had asymmetric pupils. On neurologic examination, the most common deficit was weakness or paralysis in at least 1 extremity (n = 28, 10.0%), followed by aphasia (n = 18, 6.4%), retrograde amnesia (n = 11, 3.9%), ataxia (n = 9, 3.2%), and numbness (n = 5, 1.8%). Seizures were reported in 27 patients (9.6%). There were other concomitant injuries, to the chest, abdomen, pelvis, or extremities, in 108 (40.4%) patients, and an associated injury to either the spinal column or spinal cord in 9 patients (3.2%). Fifty-eight patients (25.7%) experienced a deterioration in GCS score within 24 hours of admission.

Radiologic Findings

CT scans (Table 2) were obtained for 148 patients (52.3%), with 56.8% of patients (n = 50) with severe TBI receiving scans. Of scans that were performed, 19 (12.8%) were normal. The most common pathology seen was brain contusion (n = 73, 26.1%), followed by skull fractures (n = 63, 22.5%), epidural hematomas (n = 21, 7.5%), subarachnoid hemorrhage (n = 21, 7.5%), and subdural hematoma (n = 19, 6.8%).

Management

At the time of admission, 179 patients (67.6%) were admitted to the general ward, 25 (9.4%) were admitted to the high-dependency unit, 21 (7.9%) were admitted to the intensive care unit (ICU), and 6 (2.3%) were taken straight to the operating theater. An additional 34 patients (12.8%) died in the casualty department. Of note, 28 patients (15.6% of severe TBI patients who did not die in the casualty department) with severe TBIs were admitted to the general ward.

Neck collars were placed at any time during hospitalization in 14.3% of patients (n = 40). Burr holes for evacuation of extra-axial hematoma, or aspiration of brain abscess in the case of patients with delayed presentation, were placed in 21 patients (7.5%), with a postoperative mortality of 3 (14.3%). Mechanical ventilation was used in 25 patients (8.9%). Of patients with severe TBI who survived beyond admission, 16 (27.6%) received mechanical ventilation and 6 (10.3%) underwent tracheostomies. Eleven patients (3.9%) required elevation of a depressed skull fracture, and 16 (5.7%) received inpatient physiotherapy.

Table 2. Radiographic Findings, Interventions, and Outcomes of All Admitted Traumatic Brain Injury Patients

Findings	Number of Patients (%)
Radiographic findings (n = 233; 148 images)	
Skull fracture	63 (27.0)
Epidural hematoma	21 (9.0)
Subdural hematoma	19 (8.2)
Subarachnoid hemorrhage	21 (9.0)
Contusion	73 (31.3)
Intraventricular hemorrhage	4 (1.7)
Diffuse axonal injury	6 (2.5)
Basilar skull fracture	5 (2.1)
Subgaleal hematoma	12 (5.2)
Midline shift	9 (3.9)
Interventions (n = 280)	
Neck collar	40 (14.3)
Tracheostomy	12 (4.3)
Burr hole	21 (7.5)
Sedation	39 (13.9)
Mechanical ventilation	25 (8.9)
Elevation of skull fracture	11 (3.9)
Physiotherapy	16 (5.7)
Outcomes (n = 266)	
Discharged	174 (65.)
Transferred	6 (2.3)
Left against medical advice	5 (1.9)
Died	82 (30.9)
Functional outcomes (n = 265)	
Good recovery	148 (55.9)
Moderate disability	24 (9.1)
Severe disability	9 (3.4)
Vegetative state	2 (0.8)
Death	82 (30.9)

Outcomes

Our overall mortality (Table 2) was 30.9% (n = 82). Of these, 34 patients (41.5% of all patients who died, or 12.8% of the total population) died while in the casualty department. When stratified by severity of TBI, 41.4% (n = 24) of patients with severe TBI, compared with 31.9% (n = 15) of patients with moderate TBI and 17.0% (n = 8) of patients with mild TBI, died during their hospital stay. The mortality rate was 7.6% (n = 12) for patients whose highest level of care was the general ward, 27.3% (n = 9) for patients whose highest level of care was the high-dependency unit, and 70.6% (n = 24) for patients who received care in the ICU. Further, 69.1% of patients (n = 56) who died did not receive a CT scan.

Of patients that survived, 80.1% (n = 148) had a good recovery with no appreciable clinical neurologic deficits, 13.1% (n = 24) had a moderate disability with deficits that still allowed the patient to live independently, 4.9% (n = 9) had severe disability which will require assistance with activities of daily life, and 1.1% (n = 2) were in a vegetative state.

A bivariate analysis comparing patients by favorable functional outcome and poor functional outcome or death was performed (Table 3). There were statistically significant differences between the 2 groups in severity of their TBI, and each component of the GCS score. A survival time analysis was done (Figure 1), which showed that female sex is protective against poor functional outcome. On Cox regression analysis adjusted for age, sex, presence of severe TBI, and mechanism of injury (Table 4), only presence of severe TBI was a statistically significant predictor of poor outcome (hazard ratio, 2.98; 95% confidence interval, 1.79–4.95).

Table 3. Bivariate Analysis of All Traumatic Brain Injury Patients Stratified by Favorability of Outcome

Characteristic	Favorable Outcome (Good Recovery/Moderate Disability) (n = 172, 64.9%)	Death or Poor Outcome (n = 93, 35.1%)	*P* Value
Age, mean ± SD (years)	27.5 ± 16.3	31.3 ± 16.2	0.07
Male sex	139 (80.8)	74 (79.8)	0.81
Injury etiology			0.43
RTI	103 (59.9)	57 (61.3)	
Assault	39 (22.7)	27 (29.0)	
Fall	21 (12.2)	6 (6.5)	
Other	8 (4.7)	3 (3.2)	
TBI severity			
Mild	101 (58.7)	14 (15.1)	<0.001
Moderate	43 (25.0)	21 (22.6)	<0.001
Severe	28 (16.3)	60 (64.5)	<0.001
Time from injury to presentation at KCH, mean ± SD (days)	1.7 ± 6.8	1.6 ± 6.9	0.91
Transferred in	102 (59.7)	57 (62.0)	0.72
Admission GCS eye score	4 (3–4)	1 (1–3)	<0.001
Admission GCS verbal score	4 (3–5)	2 (1–4)	<0.001
Admission GCS motor score	6 (5–6)	4 (2–5)	<0.001
Admission GCS total score	14 (11–15)	8 (5–10)	<0.001
Associated injury to chest, abdomen, or extremities	65 (37.8)	42 (45.2)	0.15

Values are number of patients (%), median (interquartile range), or as otherwise indicated.

KCH, Kamuzu Central Hospital; GCS, Glasgow Coma Scale; RTI, road traffic injury.

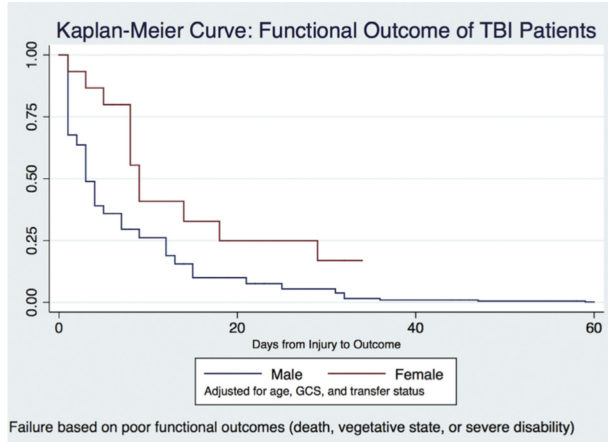

Figure 1. Survival time analysis stratified by sex, with failure defined as death, vegetative state, or severe disability. GCS, Glasgow Coma Scale; TBI, traumatic brain injury.

DISCUSSION

Most literature from sub-Saharan Africa discusses head injury, and not the more precise clinical entity of TBI.[5] To our knowledge, this study is a first report of a TBI database established at a tertiary care center in sub-Saharan Africa. The prospective collection of clinical and radiographic data on all patients presenting with TBI allows us to characterize patterns and functional outcomes in TBI, in an effort to inform public health and assess interventions to reduce morbidity and mortality in this resource poor environment. In our setting, we found that the in-hospital mortality among patients presenting with TBI is 30.9%.

Although TBI accounts for up to 10 million hospitalizations each year worldwide, it is thought that the true incidence is likely underestimated.[5] Patients with mild TBIs may never seek treatment; however, they are still subject to long-term

Table 4. Adjusted Cox Regression Analysis

Variable	Hazard Ratio	95% Confidence Interval
Age	1.01	0.99–1.03
Female sex	0.93	0.49–1.75
Presence of severe TBI	2.98	1.79–4.95
Penetrating mechanism of injury	1.26	0.49–3.27

TBI, traumatic brain injury.

impairments in memory or cognition, earning TBI the title of the "silent epidemic."[9] On the other end of the spectrum, patients with severe TBIs may die before reaching the hospital. An accurate assessment of the burden of TBI in sub-Saharan Africa is critical because its medical and socioeconomic impact in the continent with the youngest population is prohibitive.[6] Projections of TBI for the future will be required to assess the need for long-term health care, nursing homes, and the psychosocial costs of neurocognitive impairment secondary to TBI.[6]

In the United States, the estimated annual incidence of TBI is approximately 200 per 100,000 people, and the rate of hospitalization because of TBI has in fact decreased by approximately 50% since 1980. Overall TBI mortality in the United States is estimated to be 3.3%.[10] This is in contrast with many LMICs, where incidence continues to increase in recent years[11] and mortality remains high.[4]

The only population-based incidence report from sub-Saharan Africa comes from South Africa in 1991, reporting an approximate incidence of 310 per 100,000 people.[12] Unfortunately, the incidence of TBI continues to increase because more people are now able to own vehicles, and violence continues to be common in multiple regions. One modeling study predicts 6–14 million new TBI cases per year in Africa alone by the year 2050.[11] A high incidence of TBI is made worse by a disproportionately high mortality.[4] Most African studies show that TBI tends to be in men, and it tends to have 2 peaks: <10 years, and ages 15–24 years.[13-17] African studies also report that the most common causes of TBI are road traffic crashes and violence in adults, and falls in children.[5] In sub-Saharan Africa, unlike in high-income countries, there is no third peak because the average life expectancy is well below the >65 years of age group where the third peak is typically observed.[5] We also found 2 age peaks (**Figure 2**); however, our 20–30 years of age peak was much more prominent than the <10 years of age peak. Our most common mechanism of injury was road traffic crash in both adults and children, consistent with findings in all other settings. Globally, it is estimated that approximately 80% of TBIs are mild, 10% are moderate, and 10% are severe.[18] We found our percentage of patients with mild TBIs to be significantly lower than global estimates. This is likely because of presentation bias. We suspect that there may also be a higher rate of mild TBIs at the district hospitals because only the most severe cases were referred to our center, resulting in the underreporting of patients.

TBI-related mortality data from hospital-based trauma surveillance registries in other sub-Saharan African countries reveal TBI mortality of 26% and 21% in Uganda[15] and Ethiopia,[17] respectively. Our reported mortality is higher than both the United States, and other low-income settings, at 31%, despite the fact that most of our TBI patients presented on admission with a GCS score of 13–15. Among patients with mild TBI mortality was 17%. This would suggest that we are missing the opportunity to prevent or decrease secondary brain injury, and/or our ability to detect change in neurologic examination and intervene appropriately is suboptimal. This represents a significant opportunity for intervention.

Guidelines and protocols aimed at reducing secondary brain injury[19] should be implemented and adhered to. Patients should first be resuscitated in accordance with Advanced Trauma Life Support guidelines,[20] assessing the airway, breathing, and circulation in turn. Supplementary oxygen is available in the casualty department, but it is not common practice to intubate patients, even those with GCS scores ≤8, until they have been moved to the ICU. We found that only 27% of surviving patients with severe TBI were intubated to protect the airway at any time during their hospitalization. Keeping in mind that patients often have concomitant injuries, care should be taken to assess the entire patient, including the cervical spine. Only 14.3% of our patients received a neck collar at any time during their hospitalization. After patients are stabilized, it is generally recommended that any patient with a moderate to severe TBI undergo CT scanning.[21] In our setting, 48% of patients did not undergo CT scan.

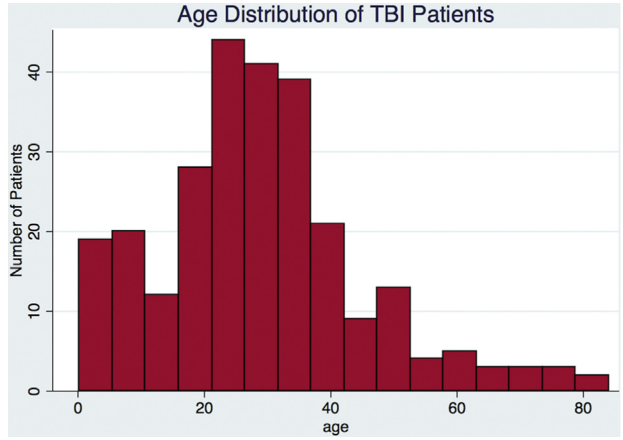

Figure 2. Age distribution of all patients admitted to Kamuzu Central Hospital with traumatic brain injury. TBI, traumatic brain injury.

Early protection of the airway, prompt CT scanning, and placement of neck collars on all trauma patients are all practices that should be improved on to optimize the care of TBI patients at our hospital. Additionally, 15% of patients with severe TBI received care in the general ward, where staffing and monitoring is limited. This poses an additional challenge because patients in the general ward do not receive frequent neurologic checks, which are critical to prompt further interventions.

One major component of secondary brain injury prevention is the management of intracranial pressure (ICP), as a precipitous rise in ICP can quickly lead to herniation and brain death. Although invasive ICP monitoring is not possible in our setting, there is no evidence to suggest that invasive ICP monitoring reduces mortality in any setting.[22] However, simple procedures aimed at maintaining a normal ICP, such as elevation of the head of the bed should be routine.[21] To prevent the devastating consequences of a sudden rise in ICP, frequent neurologic checks should be performed to detect clinical signs of increased ICP, such as a decrease in the patient's GCS score. If a sudden decrease in GCS score or the development of a lateralizing sign is detected, the patient may have an expanding extra-axial hematoma, requiring evacuation.[21] In these patients, outcome is markedly affected by the time to intervention, with hematomas requiring drainage within 4 hours to prevent significant morbidity and mortality.[23]

The standard care practices described here—timely placement of interventions such as neck collars, appropriate radiographic studies, referral of the patient to the correct level of care, and frequent neurologic checks to prompt further interventions as necessary—may all be addressed even in a resource-poor setting with the implementation of evidence-based management protocols, in which all TBI patients receive uniform multidisciplinary care based on guidelines.[24] Studies have shown that the use of management protocols for patients with severe TBI are associated with reductions in death up to 6 months after hospital discharge, and overall improved neurologic outcome.[25] Although management protocols would have to be contextualized to the setting,[26] their implementation may make it possible to ensure that all patients receive the highest level of care possible.

Our study is limited by a lack of postdischarge follow-up because long-term outcomes could not be determined. We are also unable to determine the incidence of TBI in our population because of presentation bias. We missed those patients who died prior to arrival to the hospital or present only to the district hospitals.

CONCLUSIONS

Trauma is a significant contributor to global morbidity and mortality, and a growing public health concern, particularly in LMICs. The attenuation of TBI-related morbidity and mortality is critical to reduce the global impact of trauma. In our setting, significant mortality is seen even in patients with mild TBI. Contextualized management protocols may help attenuate TBI-related mortality and improve functional outcome in our low-resource setting.

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