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ORIGINAL ARTICLE

Determinants of hospital mortality among patients presenting with Traumatic Brain Injury at the University Teaching Hospital, Lusaka, Zambia

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ABSTRACT

Background: Traumatic brain injury (TBI) is a major cause of mortality and long-term disability and economic loss to society. Studies on TBI are scarce and mostly originate from high-income countries. Low- and middle-income countries (LMICs) experience the majority TBIs, yet few studies have examined the patterns of TBIs, and the factors associated with mortality. In Zambia, the burden of TBIs is high while the mortality trends remain poorly documented. This study aimed to assess the determinants of in hospital mortality among patients presenting with TBIs at the University Teaching Hospital Lusaka, Zambia.

Methodology: This was a prospective cross-sectional study conducted among 143 TBI patients seen at the University Teaching Hospital (UTH) from September 1st to December 31st, 2023. All TBI patients, regardless of severity, were included. Descriptive statistics were used to present demographic and clinical characteristics. Chi-square tests assessed associations between categorical variables, and binary logistic regression was performed to calculate the odds of mortality associated with each predictor variable. Model selection was done using an investigator led stepwise approach. Statistically significant factors influencing mortality were identified, with a p-value < 0.05 considered significant.

Results: The study enrolled 143 TBI cases, with 13 resulting in death, giving a mortality rate of 10%. The average age of deceased patients was 39 years (SD 19), while that of the discharged patients was 32 years (SD 14). Binary logistic regression showed that a low Glasgow Coma Scale (GCS) score was associated with mortality, with each unit increase in GCS reducing the odds of death by 0.761 (95% CI: 0.578, 1.00, p=0.05). The median GCS score on admission for deceased patients was 7/15, compared

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to 14/15 for discharged patients. Subarachnoid haemorrhage was significantly associated with mortality (p=0.008). Additionally, a history of seizures after injury increased the likelihood of death by 9.324 times (95% CI: 1.12, 7.95, p=0.039), and mechanical ventilation was associated with 20.63 times higher odds of mortality (95% CI: 1.93, 220, p=0.012).

Conclusion: This study highlights that Traumatic Brain Injury (TBI) is a significant public health problem in Zambia, particularly among young males, with road traffic accidents (RTAs) and assaults being the leading mechanisms of injury. The absence of paramedic services and delays in reaching healthcare facilities with neurosurgical expertise exacerbate the problem. Key factors associated with higher mortality include the need for mechanical ventilation, post-traumatic seizures, and low Glasgow Coma Scale (GCS) scores. Early intervention, enhanced monitoring, and improving the capacity for timely mechanical ventilation are critical to reducing mortality and improving outcomes for TBI patients.

INTRODUCTION

Traumatic brain injury (TBI) is an important public health concern affecting millions of people all over the world.[1] It is one of the leading causes of morbidity and mortality, as well as a major contributor to long-term disability and societal economic loss.[2,3] Globally, TBIs are estimated to affect 69 million people[4] and cause more than 4.7 million deaths annually.[3] This is a global problem imposing a significant socioeconomic burden on patients, families, and society.[5] Low and middle-income countries (LMICs) have three times more TBI cases than high-income countries (HICs).[3] The increasing problem of TBI in LMICs can be attributed to urbanization, a growing middle class, the affordability of cars and motorcycles, and a growing population without mature healthcare systems to handle increasing incidences of trauma and injury.[6] Data indicate that TBI incidence will continue to rise significantly over the next ten years, with Sub-Saharan Africa (SSA) having a much higher incidence than other regions.[7] TBI in SSA has been poorly studied when in fact it is believed that the incidence and mortality of TBI are higher in LMICs than in HICs.[8,9] The mortality rate associated with TBIs are three to four times higher in LMICs compared to HICs.[10]

Previous studies in SSA have highlighted unique challenges, including limited access to quality healthcare, inadequate pre-hospital care, and delayed presentations to tertiary centres, all of which contribute to increased mortality rates.[11,12] Zambia, like other low-income countries has not been spared from the growing burden of TBI and its consequences. In 2016, the incidence of TBI in Zambia was estimated to be 55 681 per year, that is, 381 per 100 000 population.[13] However, few local studies have evaluated and determined independent predictors of hospital mortality among patients with TBI in the country.[14,15]

To better understand predictors of TBI mortality, a study was conducted at the UTH with a goal of identifying important sociodemographic, clinical, hospital, and pre-hospital factors associated with mortality in this patient population.

METHODOLOGY

Study Design

This study was a prospective analytical cross-sectional study conducted at the University Teaching Hospital (UTH) in Lusaka, Zambia. A cross-sectional design was deemed more appropriate for this study, given its ability to provide a snapshot of factors associated with mortality within a defined timeframe. This approach was resource-efficient, and avoided the challenges associated with longer follow-up times.

Sampling and Recruitment of Participants

The sample size was calculated using the Wald test, based on a mortality rate of 25% for moderate TBI from a similar study.[14] Assuming a 13% mortality rate under the null hypothesis, the required sample size for 90% power was calculated using Stata's "power one proportion" command, yielding a sample size of 137. A total of 143 patients were enrolled, accounting for missing data and errors. Patients without consent or missing clinical records were excluded.

Total enumeration sampling was employed due to the study's short time frame and the desire to include all patients presenting with TBI during the study period. This approach minimizes selection bias, but we acknowledge its limitations in generalizability. The study duration was kept short due to logistical constraints.

Data Collection

Data was extracted from patient records, including sociodemographic information (age, gender), clinical characteristics (Glasgow Coma Scale score, TBI severity), and outcomes (mortality, length of hospital stay). To ensure accuracy, data entry was double-checked by a second researcher, and any discrepancies were resolved through consultation with the primary researcher. The data collection tool was based on validated instruments from previous studies and was refined to fit the study objectives. Multiple data collectors were involved, with standardized training and regular meetings to ensure consistency in data recording.

Sources of bias

Potential biases in this study include selection bias due to the single-centre design and information bias, due to reliance on clinical records. Efforts were made to minimize these biases by ensuring clear data entry protocols and using reliable hospital records. While inter-rater reliability was not formally tested, all data collectors underwent uniform training to maintain consistency. The single-centre design limits external validity, but the findings are still relevant to similar settings in Zambia and other low-resource countries.

Data Analysis

Descriptive Statistics

Descriptive statistics were used to summarize the data. Categorical variables (such as gender, TBI severity) were presented as frequencies and percentages, while continuous variables (such as age and length of stay) were summarized using means and standard deviations for normally distributed data, or medians and interquartile ranges for non-normally distributed data. The distribution of variables was visually represented using bar graphs and histograms.

Analytical Statistics

Associations between categorical variables (e.g., TBI severity and mortality) were tested using the chi-square test. For continuous variables (e.g., age and length of stay), comparisons between groups were made using the t-test for normally distributed data and the Mann-Whitney U test for non-normally distributed data.

Variable Selection and Regression Analysis

To identify independent predictors of mortality, binary logistic regression analysis was performed. Variables that were significant at a p-value of <0.05 in univariate analysis were included in the multivariate model to adjust for potential confounders. Confounders, such as age and injury severity, were carefully considered and adjusted for in the model. A 95% confidence level was used for all tests, and odds ratios with corresponding confidence intervals were reported for significant predictors of mortality.

ETHICAL CONSIDERATIONS

The study protocol was approved by the University of Zambia Biomedical Research Ethics Committee (UNZA-BREC) (Reference Number 3640-2023) and cleared by the National Health Research Authority (NHRA) (Reference Number NHRA 00001/12/04/2023). Permission to conduct the study at UTH was granted by the institution's administration. All ethical requirements were followed/ observed during the conduct of the study.

RESULTS

A total of 143 participants were enrolled, with a mean age of 34 years (SD ±16). The mean age of those who died was 39 years (SD ±19), compared to 32 years (SD ±14) for survivors ($p = 0.306$). Males represented 90% of the sample, with a higher likelihood of sustaining TBI than females (2.94 times more likely, 95% CI: 0.704-12.33, p = 0.146). The primary causes of injury were road traffic accidents (RTAs) (60%), followed by assaults (22%), with no significant correlation between the mechanism of injury and mortality.

Table 1: Baseline characteristics and vital observations on arrival at UTH

Characteristic	**Outcome**		**p-value**
	Discharged N=119(90%)	**Died N=13 (10%)**	
Age: mean (SD)	32 (14)	39(19)	0.306
Sex Male Female Missing (n=1)	 107(91%) 11(9%)	 10(77%) 3(23%)	0.146
Glasgow Comma Scale: Median	14/15	7/15	**0.042**
Systolic BP: Mean (SD)	128 (20)	140 (26)	**0.**042
Diastolic: Mean (SD)	83(13)	88(17)	0.372
Oxygen Saturation	95(6)	96(4)	0.631
HR (beats per minute)	92(48)	100(17)	0.585
Pupillary examination Normal Abnormal Missing (n=7)	 94(83%) 20(17%)	 4(31%) 9(69%)	**0.001**
Focal neurologic deficits Present Absent Missing (n=19)	 30(29%) 74(71%)	 2(18%) 9(82%)	0.515
Skull base fracture features Present Absent Missing (n=13)	 25(23%) 83(77%)	 1(8%) 11(97%)	0.216
Associated injuries Present Absent Missing (n=6)	 46(40%) 67(60%)	 7(54%) 6(46%)	0.388
Mechanical ventilation Yes No Missing (n=13)	 19 (18%) 88(82%)	 12(92%) 1(8%)	**0.001**
History of seizures Yes No Missing (n=9)	 12(11%) 100(89%)	 5(38.5%) 8(61.5%)	**0.017**
Type of injury sustained Skull fracture Cerebral oedema Epidural haematoma Subdural haematoma Subarachnoid haemorrhage Contusion Intracerebral haematoma	 16(15%) 22(21%) 3(3%) 14(13%) 10(10%) 17(1.0%) 0(0.0%)	 0(0.0%) 1(8%) 0(0.0%) 2(17%) 5(42%) 3(0.0%) 1(8%)	**0.008**
Non-operative intervention	78(92.5%)	9(7.5%)	0.611
Operative intervention Wound debridement Hematoma evacuation Fracture elevation Total	 3(8%) 16(45%) 17(47%) 37(100%)	 0(0.0%) 3(100.0%) 0(0.0%) 3(100%)	0.293

Regarding RTAs, pedestrians were the most affected, though the type of RTA victim did not significantly affect mortality.

Most patients 115(82%) were referrals, with 123(89%) using private vehicles for initial transport to healthcare facilities. Most patients (90%) had loss of consciousness for more than 30 minutes. The interval from injury to hospital presentation ranged from 0-6 hours in 45(35%) of cases, 14 (11%) within 24 hours to 3 days, another 14 (11%) within 3-7 days, and 12 (9%) after more than one week but there was no significant relationship between time to presentation and mortality. Suspected alcohol intoxication was reported in 31 cases (23%), but there was no significant association between alcohol use and mortality.

A total of 127 patients (90%) experienced loss of consciousness lasting longer than 30 minutes, while seizures were reported in 19 cases (14%). There was a statistically significant association between the history of seizures at presentation and mortality. Patients who died had a higher likelihood of experiencing post-trauma seizures.

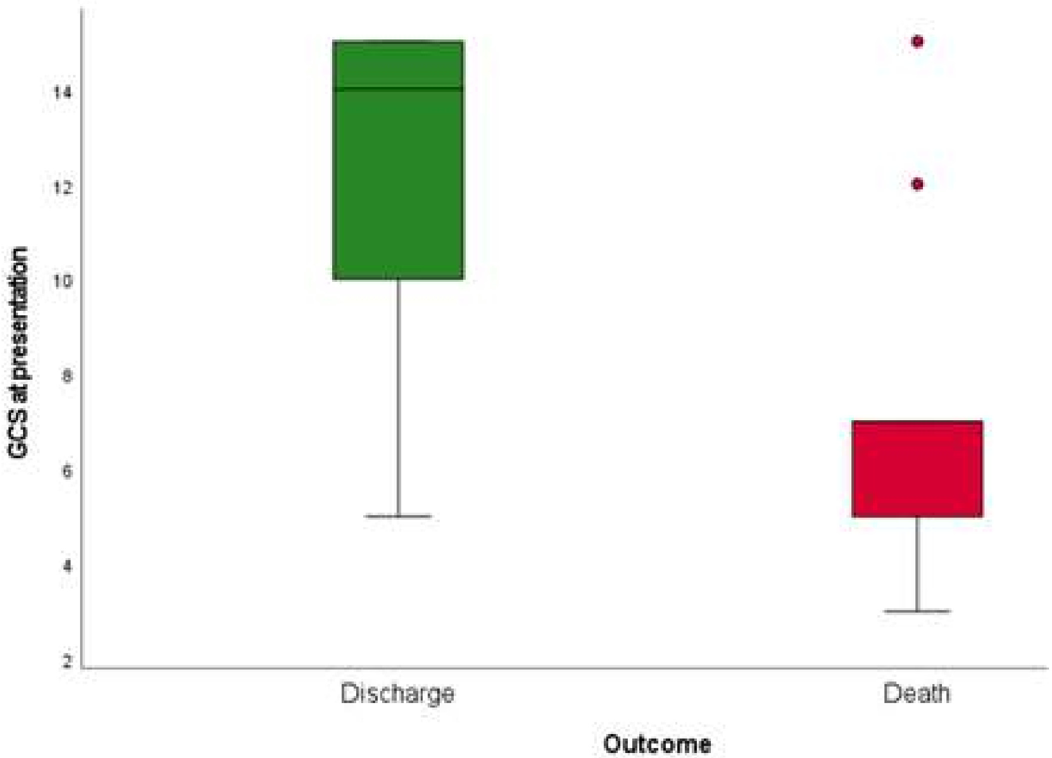

Figure 2: Box plot showing GCS score in discharged and mortality groups.

Out of 143 participants, 27 (19%) had severe TBI (GCS < 8), 48 (34%) moderate TBI (GCS 9-12), and 61 (43%) mild TBI (GCS $\geq$14). The mortality rate was 75% among severe TBI patients (n=9). The median GCS at presentation was 13 (IQR 10-15), with deceased patients having a lower median GCS (7 vs. 14, p < 0.001).

The mean systolic blood pressure at admission was 129 mmHg (SD 20), with deceased patients having higher systolic BP (140 mmHg, SD 26). A significant association between systolic BP and mortality was observed, with those who died having a higher mean systolic BP (140 mmHg, SD 26 mmHg) compared to those discharged (128 mmHg, SD 20 mmHg). Abnormal pupillary findings were significantly associated with mortality (OR 10, 95% CI: 3-37, p < 0.001). In contrast, focal neurologic deficits and skull base fracture features did not show any significant relationship with mortality. Subarachnoid haemorrhage was also significantly associated with mortality (p = 0.008).

Of the 36(27%) patients who underwent surgery, 3 died post-operatively. Mechanical ventilation was required for 33 (25%, n=33) patients, and among these, 12 (36%, n=12) died during admission, showing a statistically significant association between the need for mechanical ventilation and mortality (p=0.001).

Overall, 13 patients (10%) died, with most fatalities occurring in the ICU (70%, n=9). The mortality rate was 10%, and 119 (90%) were discharged.

Regression Analysis

Table 2 : Multivariable logistic regression analysis of factors associated with mortality in TBI patients presenting at UTH

Independent variables	**Univariate logistic regression**			**Multivariate logistic regression**		
	c.OR	**95% CI**	**p - value**	**a.OR**	**95% CI**	**p - value**
Age	1.028	(0.99, 1.07)	0.165			
Sex Male Female	0.143	(0.08, 1.43)	0.343			
Glasgow Comma Scale	0.639	(0.51, 0.80)	**0.0001**	0.761	(0.578 1.00)	**0.052**
Systolic BP: Mean (SD)	1.03	(1.00, 1.06)	**0.048**			
Pupillary examination Normal (1) Abnormal	0.095	(0.026 0.34)	**0.0001**			
Mechanical ventilation Yes No	56	(6.81, 454)	**0.0001**	20.63 2	(1.93 220)	**0.012**
History of seizures Yes No	5.20	(1.47, 18.50)	**0.011**	9.324	(1.12, 7.95)	**0.039**

Univariate analysis was performed to identify factors associated with mortality. Age (crude OR 1.028, 95% CI 0.99-1.07, p=0.165) and sex (crude OR 0.143, 95% CI 0.08-1.43, p=0.343) were not significantly associated with mortality. However, the Glasgow Coma Scale (GCS) score (crude OR 0.639, 95% CI 0.51-0.80, p=0.0001) was significantly associated with mortality, where each one-unit increase in GCS score reduced the odds of death by 36%. Similarly, systolic BP showed a significant result in the univariate analysis (crude OR 1.03, 95% CI 1.00-1.06, p=0.048), indicating that each one-unit increase in systolic BP was associated with a 3% increase in the odds of mortality. Mechanical ventilation (crude OR 56.48, 95% CI 6.81-454, p=0.0001) was associated with a dramatically higher odds of death, and a history of seizures following TBI (crude OR 5.01, 95% CI 1.47-18.50, p=0.011) was associated with five times higher odds of mortality.

Significant variables from the univariate analysis were included in a multivariate logistic regression model. In the stepwise forward binary logistic regression, the following variables remained significant:

GCS Score: Each one-unit increase in GCS score was associated with a reduced risk of death (adjusted OR 0.761, 95% CI 0.578-1.00, p=0.052). This suggests that patients with higher GCS scores had better survival outcomes.

Mechanical Ventilation: Patients who required mechanical ventilation had significantly higher odds of death (adjusted OR 20.632, 95% CI 1.93-220, p=0.012), highlighting that the need for ventilation was a critical predictor of mortality.

History of Seizures: A history of post-traumatic seizures increased the odds of mortality (adjusted OR 9.324, 95% CI 1.12-7.95, p=0.039), indicating that seizures were a strong predictor of poor outcomes.

The model's Nagelkerke R Square was 0.545, indicating that these three factors (GCS score, mechanical ventilation, and history of seizures) explained 54.5% of the variability in mortality. This underscores the importance of neurological status and the need for mechanical support as critical determinants of survival in patients with TBI.

DISCUSSION

This study aimed to determine factors associated with hospital mortality among patients with TBI at the UTH in Lusaka, Zambia. Important determinants of mortality identified included TBI severity, need for mechanical ventilation, presence of subarachnoid haemorrhage and post-traumatic seizures.

Socio-demographic factors associated with hospital mortality in patients presenting with TBI at the UTH

The study found that 127(90%) of TBI patients were male, with over half 80(56%) aged 21-40, representing the economically active age group. This is similar to previous studies in Uganda[16], Seychelles[17], Rwanda[18], and South Africa[19], which found that most TBIs occurred in young patients aged 19-40. Younger populations, being more active, are more likely to be involved in risky events or activities. Studies in high-income countries, however, report older populations sustaining TBI with a median age of 53 in one study[20], reflecting the demographics of aging adults in these countries. Morbidity and mortality due to TBI in the young have severe consequences on a nation's socio-economic status and future prosperity.[21]

The study found that males are 8 times more likely to present with TBI compared to females, but no significant differences in mortality trends across gender were found. Previous studies have found that male gender is associated with higher mortality risk in patients with TBI.[22] However, other studies show that women generally have an advantage in survival following TBI[23], but this may not be equally reproducible in premenopausal women.[24] The pathophysiology of TBI and sex differences are still poorly understood. Multiple factors, including injury severity, sample size, and other confounding factors, may interact differently with sex to affect TBI outcomes

The estimated hospital mortality rate associated with TBI at the UTH

The study found a 10% TBI case fatality rate, lower than the 25.6% reported in 2015 at UTH.[14] This may be due to improvements in care quality over the past 8 years, such as a dedicated emergency physician unit, increased ICU capacity, and more neurosurgeons. The findings were similar to those in Ethiopia 12.7%[25], Nigeria (10.1%)[26], and Uganda 12.1%.[27] However, higher mortality rates have been reported in Ethiopia 30.45%[28], and China 26.4%[29], with other countries like Nigeria 5%[30], and Saudi Arabia, 4.7%[31], reporting lower mortality rates. Variations in mortality rates may be due to differences in hospital standards, severity of traumatic brain injuries, and access to resources like imaging and diagnostic tests.

Mechanisms of injury associated with hospital mortality in patients presenting with TBI at the UTH

This study found that road traffic accidents (86%), assault (22%), and falls (19%) are the leading causes of traffic-related injuries (TBIs). We observed that the majority (48%) of RTA victims who sustained TBI were pedestrians This pattern is also observed in low-income countries (LMICs) and Sub-Saharan Africa, such as Nigeria, Ethiopia, and Uganda.[22,32.33] Rapid urbanization in these countries has led to increased motorization and expanded road networks, often outpacing the development of road safety measures and infrastructure.[34] Enforcement of road safety regulations remains a challenge in LMICs, with low adherence to seatbelt, helmet, and child restraint systems and high prevalence of driving under the influence of alcohol. Poor road infrastructure, such as lack of signage and pedestrian crossings, further exposes pedestrians to risk. Higher-income countries like Norway and New Zealand have reported lower pedestrian TBIs and this may be attributed to their more developed road infrastructure and effective enforcement of road safety regulations.[20]

The study reveals that motorcycles account for 23% of road traffic accidents in Zambia, a stark contrast to studies in East Africa[35] and Rwanda[18], where nearly 60% of RTAs resulting in traumatic brain injuries involve motorcycles.[36] This may be due to the higher prevalence of motorcycle use in these regions. However, the use of motorcycles in Lusaka, Zambia is increasing due to the rise of motorbike courier businesses. The Road Transport and Safety Agency (RTSA) reported that motorcycles accounted for 2% of all road traffic accidents in 2018, and by 2021, it had doubled to 5%.[37] The low usage of helmets in Zambia[37], and the increased risk of death for pedestrians and motorcyclists with TBIs are concerning public health issues.

Severe traumatic brain injury as a determinant of mortality

Patients presenting with a lower Glasgow Coma Scale (GCS) score were at a higher risk of death in this study. This finding aligns with multiple studies that have reported a strong association between low GCS scores and poor outcomes in TBI patients.[38,39] Severe brain injuries are often accompanied by impaired cerebral autoregulation, increased intracranial pressure, and brainstem dysfunction, all of which contribute to early mortality.[40] In Zambia, where access to advanced neuroimaging and intensive care resources is limited, the prognosis for patients with severe TBI remains poor despite recent improvements in emergency care. Early identification and aggressive management of these cases, such as timely intubation and intracranial pressure monitoring, are crucial to improving outcomes.

Mechanical ventilation as a determinant of mortality

Patients requiring mechanical ventilation had significantly higher mortality rates than those who did not require ventilatory support, consistent with findings from studies in Nigeria and the USA.[41,26] The need for ventilation typically reflects the increased severity of brain injury, including respiratory failure due to damage to the brainstem centres regulating breathing. In LMICs like Zambia, mechanical ventilation is not only a marker of severe injury but also a potential contributor to poorer outcomes due to the limited availability of critical care resources. Allocating more resources (such as staffing, equipment and consumables) towards critical care, as well as optimizing mechanical ventilation protocols may help in reducing mortality among TBI patients.

Subarachnoid haemorrhage as a determinant of mortality

The presence of subarachnoid haemorrhage (SAH) was also significantly associated with mortality.

This finding is supported by other studies that have demonstrated a higher risk of death in TBI patients with SAH and have ascribed this to the increased likelihood of secondary brain injury related to vasospasms, re-bleeding, and hydrocephalus.[42,43] In our study, these patients often presented with more severe neurological impairment and required urgent neurosurgical intervention. Timely surgical management and intensive monitoring for complications are essential for improving survival in these high-risk patients.[44] The high mortality rate among traumatic SAH patients underscores the need for better diagnostic capabilities and more effective neurocritical care management in resource-limited settings like UTH.[45]

Post-traumatic seizures as a determinant of mortality.

The study found that TBI patients had a higher mortality risk when they experienced post-traumatic seizures. Post traumatic seizures have been associated with greater morbidity and mortality in several studies.[46,47] Studies evaluating risk factors for the development of post traumatic seizures are relatively few. These seizures are categorized by their onset: immediate seizures occur within the first 24 hours, early seizures develop between 24 hours and one week, and late seizures arise after one week of the injury.[48] Key risk factors for post-traumatic seizures include the increased TBI severity[46], subdural hemorrhage[49] and brain contusion.[49] The underlying pathophysiology is complex, involving mechanisms such as direct neuronal damage, excitotoxicity, neuroinflammation, structural changes, blood-brain barrier dysfunction, and secondary brain insults.[50] In hospital settings, the early detection and management of post-traumatic seizures could be critical in reducing mortality, particularly in patients with severe TBIs, where seizures are more likely to occur.

CONCLUSION AND RECOMMENDATIONS

The study found a decrease in Traumatic Brain Injury (TBI) mortality rates at UTH, likely due to better access to imaging and timely neurosurgical interventions. However, severe TBI, subarachnoid haemorrhage, mechanical ventilation, and post-traumatic seizures remain significant risk factors for mortality. TBI is most prevalent among young and middle-aged males, particularly from pedestrian accidents. The study emphasizes the need for improved pre-hospital care and emergency services in Zambia.

The recommendations include introducing a standard TBI clerk sheet, enhancing trauma care protocols and better-equipped emergency medical services. Public adherence to traffic regulations, especially on weekends, is vital to prevent TBIs. Future research should focus on multi-centre studies with larger sample sizes and allocate more resources to TBI research in Zambia.

STUDY STRENGTHS AND LIMITATIONS

This study investigates the factors affecting mortality in patients with Traumatic Brain Injury (TBI) in Zambia, a low- and middle-income country. The research was conducted at a major referral hospital, allowing for a wide range of TBI severity to be captured. The study used binary logistic regression to identify independent predictors of mortality, controlling for potential confounders like age, injury severity, and time to intervention. However, the study had limitations, including a small sample size of 143 patients, which may limit the statistical power and precision of the estimates. The study was conducted at a single public hospital, which may introduce selection bias and limit the generalizability of the findings to patients with TBI in other settings. Additionally, convenient sampling during a specific period may impact the generalizability of the results. The study relied on existing medical records, which may vary in quality and completeness.

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Conflict of interests

The authors declare no conflict of interest. They have no personal, financial, or institutional interest in any

of the materials or surgical procedures described in this article.

Data availability

Further data is available from the corresponding author on reasonable request.

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