Anatomic Location and Mechanism of Injury Correlating with Prehospital Deaths in Sub-Saharan Africa

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Abstract

Introduction Trauma is a large contributor to morbidity and mortality in developing countries. We sought to determine which anatomic injury locations and mechanisms of injury predispose to prehospital mortality in Malawi to help target preventive and therapeutic interventions. We hypothesized that head injury would result in the highest prehospital mortality.

Methods This was a retrospective analysis of all trauma patients presenting to Kamuzu Central Hospital in Lilongwe, Malawi, from 2008 to 2015. Independent variables included baseline characteristics, anatomic location of primary injury, mechanism of injury, and severity of secondary injuries. Multivariable logistic regression was used to assess the effect of primary injury location and injury mechanism on prehospital death, after adjusting for confounders. Effect measure modification of the primary injury site/prehospital death relationship by injury mechanism (stratified into intentional and unintentional injury) was assessed.

Results Of 85,806 patients, 701 died in transit (0.8%). Five hundred and five (72%) of these patients sustained a primary head injury. After adjustment, head injury was the anatomic location most associated with prehospital death (OR 11.81 (95% CI 6.96–20.06, $p < 0.0001$). The mechanisms of injury most associated with prehospital death were gunshot wounds (OR 38.23, 95% CI 17.66–87.78, $p < 0.0001$) and pedestrian hit by vehicle (OR 2.62, 95% CI 1.92–3.55, $p < 0.0001$). Among head injury patients, the odds of prehospital mortality were higher with unintentional injuries.

Conclusions Head injuries are the most common causes of prehospital death in Malawi, while pedestrians hit by vehicles are the most common mechanisms. In a resource-poor setting, preventive measures are critical in averting mortality.

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Introduction

Trauma is the sixth leading cause of death in the world, with persons in low- and middle-income countries (LMICs) accounting for 89% of those deaths [1]. The cost of trauma-related morbidity is approximately US$671 billion in direct health care and associated loss of productivity costs in the USA alone [2]. The burden of disease is significant; between 1,730,000 and 1,965,000 lives could be saved if global trauma care were improved in LMICs [3]. Both mechanism of injury and anatomic location of injury are independent predictors of mortality and functional impairment; however, these indicators have been mostly studied in high-income countries (HICs) [4]. In the USA, pedestrians struck by motor vehicle are at highest risk of mortality and head-injured patients account for 60% of deaths [5]. Data regarding the generalizability of these predictors in a resource-poor setting are unknown.

In this study, we sought to characterize the mechanism and location of injury most associated with mortality in the resource-poor setting of Lilongwe, Malawi. We hypothesized that pedestrian struck by vehicle and traumatic brain injury (TBI) would be the deadliest mechanism of injury and location of injury, respectively.

Methods

This is a retrospective study of prospectively collected trauma surveillance data on all patients presenting to Kamuzu Central Hospital (KCH), Lilongwe, Malawi, between January 2008 and December 2015. KCH is an approximately 1000-bed hospital that serves a catchment area of five million people. The healthcare system in Malawi is reflective of British colonial Africa. It is a tiered system of primary health centers, district hospitals, and tertiary central hospitals without a formal prehospital trauma system. At KCH, trauma patients in the area present either directly to KCH or indirectly from the district hospitals or health centers. Health care in Malawi is free at the point of service. In partnership with KCH, the University of North Carolina has established a hospital-based trauma surveillance registry to capture injury characteristics and outcomes. Malawi is uniquely suited to this investigation given that all prehospital deaths are brought to the hospital and examined by a physician to determine cause of death. Thus, the registry is able to capture the majority of trauma-related deaths, an uncommon occurrence in a resource-poor setting.

Trauma resulting from assault, automobile accidents, collapsed structures, falls, gunshot wounds, and pedestrians impacted by a vehicle were eligible for inclusion. We determined baseline demographic information, injury severity, and injury characteristics. Primary injury locations were classified as head, spine, chest, abdomen/pelvis, lower extremity, and upper extremity. In poly-trauma, the primary injury location was the location of injury deemed most severe based on clinical examination by the physician. Secondary injuries and overall severity of injury were assessed via the Kampala Trauma Score (KTS), a validated trauma score ideal for low-resource settings. The score incorporates age, systolic blood pressure, neurologic status, respiratory rate, and number of severe injuries [6, 7]. Data did not exist on comorbidities given that many patients have limited access to health care. Patients missing data on age (n = 726), sex (n = 68), injury location (n = 891), or admission disposition (n = 383) were excluded.

The primary outcome of interest was prehospital mortality, as documented by a physician as "brought in dead." Patient demographics and injury characteristics, stratified by status on arrival, were compared using Chi-square and Wilcoxon–Mann–Whitney tests, where appropriate. A p value <0.05 was considered significant. Because KTS was missing for 41.5% of patients (n = 35,628), inverse probability of missing weights was calculated. Briefly, the probability of not having KTS missing was estimated using multivariable logistic regression, adjusting for season of injury, sex, age, injury mechanism, and primary injury location. These weights were stabilized by overall probability of not missing KTS, stratified by injury mechanism. Because KTS was an important potential confounder and had non-ignorable missing, a complete-case analysis (i.e., dropping patients with missing KTS from the multivariable analysis) would have likely led to biased estimates, as patients with KTS measured are likely different from those with it missing. Missingness weights allow us to match the distribution of measured covariates in patients with KTS measured to that of the entire patient population, thereby removing potential confounding by these variables (i.e., change the missingness assumption from missing completely at random [MCAR], which is rarely true, to missing at random [MAR], which assumes that missingness is random within each covariate strata) [8].

Inverse probability of missingness weighted multivariable logistic regression was used to estimate the effect of injury mechanism on the odds of being dead on arrival, after adjusting for confounders. To account for the missingness weights, robust sandwich estimators were used to estimate all 95% confidence intervals.

Additionally, the potential effect measure modification of the primary injury location/prehospital death relationship by injury mechanism was assessed. Injury mechanisms were categorized as intentional (assault and gunshot wounds) and unintentional (automobile accidents, collapsed structures, falls, and being hit by a vehicle). Significant modification was assessed using a likelihood ratio test.

All analyses were performed using SAS 9.4 (SAS Inc., Cary, NC, USA).

Results

Overall, 85,806 trauma patients presented to KCH from 2008 to 2015. Patients brought in dead were more likely to be older (median age 30 vs. 24, $p < 0.0001$), male (84.5 vs. 73.3%, $p < 0.0001$), to have been a pedestrian hit by a vehicle (33.2 vs. 9.5%, $p < 0.0001$), have a gunshot wound (7.4 vs. 0.2%, $p < 0.0001$), or have been in an automobile accident (25.5 vs. 20.5%, $p = 0.001$), as given in Table 1. Additionally, patients brought in dead were more likely to have head injuries (72.0 vs. 31.2%, $p < 0.0001$), abdomen/pelvis injuries (6.9 vs. 4.6%, $p = 0.006$), or chest injuries (6.9 vs. 5.2%, $p = 0.04$). As expected, the patients brought in dead had higher median KTSs than those brought in alive, at 5 (IQR 4–7) and 1 (IQR 1–7), respectively. The rate of prehospital mortality did not significantly change between 2008 and 2015, $p = 0.20$.

Injury mechanism was also significantly associated with injury location. Patients with intentional injuries were significantly more likely to have head injuries (57.2 vs. 22.0%, $p < 0.0001$), chest injuries (6.6 vs. 4.8%, $p < 0.0001$), spine injuries (5.0 vs. 3.6%, $p < 0.0001$), and less likely to have both upper extremity (19.6 vs. 36.2%, $p < 0.0001$) and lower extremity (7.2 vs. 28.9%, $p < 0.0001$) injuries. No difference was seen in the incidence of abdomen injuries between intentional and unintentional injury mechanisms (4.6 vs. 4.4%, $p = 0.13$.)

After adjustment, patients with gunshot wounds (OR 38.23, 95% confidence interval [CI] 17.66–87.78, $p < 0.0001$) and pedestrians hit by a vehicle (OR 2.62, 95% CI 1.93–3.55, $p < 0.0001$) were significantly more likely to be brought in dead compared to patients who were in automobile accidents, as given in Table 2. Patients who were assaulted (OR 0.70, 95% CI 0.52–0.93, $p = 0.02$) or who fell (OR 0.11, 95% CI 0.05–0.23, $p < 0.0001$) were significantly less likely to be brought in dead compared to patients in automobile accidents. No significant difference was seen between collapsed structure injuries and automobile accidents (OR 0.68, 95% CI 0.38–1.23, $p = 0.21$). Patients with head injuries (OR 11.81, 95% CI 6.96–20.06, $p < 0.0001$), abdomen/pelvis injuries (OR 8.37, 95% CI 4.41–12.23, $p < 0.0001$), chest injuries (OR 6.41, 95% CI 3.3–12.23, $p < 0.0001$), and spine injuries (OR 4.85, 95% CI 2.30–10.23, $p < 0.0001$) were more likely to be brought in dead compared to lower extremity injuries, as given in Table 2. No significant difference was seen between upper and lower extremity injuries (OR 1.29, 95% CI 0.65–2.58, $p = 0.47$). We evaluated head injury in relation to all other injury sites individually. Compared to all other injury sites, head injuries were over 4 times more likely to result in prehospital death, even after adjustment (OR 4.78, 95% CI 3.65–6.26, $p < 0.0001$).

Finally, we found that the injury mechanism (when stratified into intentional and unintentional injuries)

Table 1 Patient demographics and injury characteristics, stratified by admit disposition

	Brought in dead 701 (0.8%)	Brought in alive 85,105 (99.2%)	*p* value
Sex, *n* (%)			
Male	593 (84.6)	62,356 (73.3)	**<0.0001**
Female	108 (15.4)	22,749 (26.7)	–
Age, in years, median (IQR)	30 (22–35)	24 (12–33)	**<0.0001**
Mechanism of injury, *n* (%)			
Assault	190 (27.1)	23,981 (28.2)	0.53
Automobile accident	179 (25.5)	17,478 (20.5)	**0.001**
Bite from human/animal	2 (0.3)	3105 (3.6)	**<0.0001**
Collapsed structure	28 (4.0)	4960 (5.8)	**0.04**
Fall	17 (2.4)	27,332 (32.1)	**<0.0001**
Gunshot wound	52 (7.4)	186 (0.2)	**<0.0001**
Pedestrian hit by vehicle	233 (33.2)	8063 (9.5)	**<0.0001**
Injury location, *n* (%)			
Head	505 (72.0)	26,560 (31.2)	**<0.0001**
Spine	23 (3.3)	3333 (3.9)	0.39
Chest	48 (6.9)	4379 (5.2)	**0.04**
Abdomen/pelvis	48 (6.9)	3950 (4.6)	**0.006**
Upper extremity	30 (4.3)	26,758 (31.4)	**<0.0001**
Lower extremity	47 (6.7)	20,125 (23.7)	**<0.0001**
KTS category, median (IQR)	5 (4–7)	1 (1–7)	**<0.0001**
Missing	283	35,345	–

Bold values indicate statistical significance ($p < 0.05$)

IQR interquartile range, *KTS* Kampala Trauma Score

Table 2 Crude and adjusted effects of injury mechanism and location on prehospital death

	Crude		Adjusted[a]	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Mechanism of injury				
Assault	0.77 (0.63, 0.95)	**0.01**	0.70 (0.52, 0.93)	**0.02**
Automobile accident	Ref	–	Ref	–
Collapsed structure	0.55 (0.37, 0.82)	**0.004**	0.68 (0.38, 1.23)	0.21
Fall	0.06 (0.04, 0.10)	**<0.0001**	0.11 (0.05, 0.23)	**<0.0001**
Gunshot wound	27.30 (19.41, 38.39)	**<0.0001**	38.23 (17.66, 87.78)	**<0.0001**
Pedestrian hit by vehicle	2.82 (2.32, 3.44)	**<0.0001**	2.62 (1.93, 3.55)	**<0.0001**
Injury location				
Head	7.55 (5.60, 10.19)	**<0.0001**	11.81 (6.96, 20.06)	**<0.0001**
Spine	2.76 (1.67, 4.55)	**<0.0001**	4.85 (2.30, 10.23)	**<0.0001**
Chest	4.36 (2.91, 6.52)	**<0.0001**	6.41 (3.36, 12.23)	**<0.0001**
Abdomen/pelvis	5.11 (3.41, 7.65)	**<0.0001**	8.37 (4.41, 15.88)	**<0.0001**
Upper extremity	0.46 (0.29, 0.72)	**0.0008**	1.29 (0.65, 2.58)	0.47
Lower extremity	Ref	–	Ref	–

Bold values indicate statistical significance ($p < 0.05$)

OR odds ratio, *CI* confidence interval

[a]Adjusted for patient sex, age, KTS, year, and season of injury; inverse probability of missingness weights were used to account for the missing KTSs

significantly modified the injury location/prehospital death relationship, $p < 0.0001$, as given in Table 3. Patients with intentional head injuries were significantly less likely to be brought in dead compared to those with unintentional head injuries (OR 0.50, 95% CI 0.38–0.66, $p < 0.0001$), and patients with intentional chest injuries were more likely be brought in dead compared to unintentional chest injuries (OR 3.80, 95% CI 1.65–8.77, $p = 0.002$). No significant differences in the odds of prehospital mortality between intentional and unintentional spine injuries ($p = 0.47$), abdomen/pelvis injuries ($p = 0.65$), or upper extremity injuries ($p = 0.18$) were seen. Similar results were found when a complete-case analysis was performed without KTS measured (data not shown).

Table 3 Adjusted effects of primary injury location on prehospital death, stratified by injury mechanism

	Intentional[a] OR (95% CI)[c]	Unintentional[b] OR (95% CI)[c]	*p* value
Injury location			
Head	11.74 (6.10, 22.59)	23.41 (12.42, 44.15)	**<0.0001**
Spine	13.25 (5.15, 34.09)	3.08 (1.02, 9.26)	0.47
Chest	20.65 (9.50, 44.90)	5.43 (2.15, 13.74)	**0.02**
Abdomen/pelvis	17.71 (7.61, 41.22)	11.88 (5.58, 25.29)	0.65
Upper extremity	2.33 (0.88, 6.18)	0.97 (0.42, 2.27)	0.18
Lower extremity	Ref	Ref	–

Bold values indicate statistical significance ($p < 0.05$)

OR odds ratio, *CI* confidence interval

[a]Includes assault and gunshot wounds

[b]Includes automobile accidents, collapsed structures, falls, and being hit by a vehicle

[c]Adjusted for patient sex, age, KTS, year, and season of injury; inverse probability of missingness weights were used to account for the missing KTSs

Discussion

In this study, we found that among trauma patients presenting to KCH, the burden of disease incurred by head injuries is substantial, with head injury accounting for 72% of all patients brought in deceased. More than 10 times as many patients died from head injuries overall compared to chest injuries and abdominal and pelvic injuries. In terms of mechanism of injury, gunshot wounds and pedestrians hit by vehicle were most associated with prehospital death; however, gunshot wounds only accounted for 7.4% of all patients brought in dead making their contributions to prehospital death less salient.

Our findings are consistent with the other studies that have examined the epidemiology of trauma in sub-Saharan Africa. Specifically, data in pediatric patients in Africa have demonstrated head injury to be the most lethal form of injury [9, 10]. A study evaluating 165,000 pediatric TBI patients revealed that children with head injuries were more likely to be pedestrians struck by vehicles in LMICs in Africa and Asia, as opposed to vehicle occupants in higher-income countries [11]. One investigation in Tanzania revealed statistically higher mortality rates among TBI victims compared to all other locations of injury [10]. Our own evaluation of in-hospital trauma mortality at KCH supports the morbidity and mortality associated with TBI in this population [12, 13].

These data are valuable windows into the trauma patterns of developing countries; however, a dearth of information exists, particularly on prehospital deaths. An analysis of death registry systems on a global scale discovered that only 20 of 83 countries possess high-quality data, and most of these countries are high-income states [14]. In studies of trauma in the USA, pedestrian struck by vehicle is the mechanism most associated with mortality [4]. Brain injury does account for the majority of prehospital deaths at 50%, followed by heart or aortic injury at 17%. The majority of deaths secondary to brain injuries occur within the first 2 days after trauma [15–17]. Our finding that 72% of prehospital deaths in Malawi are secondary to head injuries highlights the opportunities for improvement in the Malawian prehospital system. The more information garnered about injury patterns in LMICs, the more capable we will be at reducing morbidity and mortality associated with trauma in resource-poor nations.

The findings of this investigation are not surprising given the lack of mature trauma systems in sub-Saharan Africa outside South Africa. The absence of helmet laws in Malawi predisposes this population to head trauma. Multiple studies have demonstrated reduced mortality and decreased severity of nonlethal head injury with the use of helmets [18]. Additionally, seatbelts reduce the incidence of TBI and significantly diminish overall motor vehicle mortality [19]. Seatbelt regulations are deficient, and there are no restrictions on the number of passengers per vehicle in Lilongwe. Previous studies have demonstrated that altering the built environment can play a large role in trauma prevention, particularly in the incidence of pedestrians being struck by vehicles [20–23]. In Malawi, a lack of sidewalks, crosswalks, and medians places pedestrians at risk of injury. Ideally, public health prevention would address these issues; however, realistically, the country lacks the resources and capital to invest in prevention as a primary focus.

The dearth of emergency first responder personnel and lack of dispatch structure may the greatest contributors to prehospital deaths in Malawi. In the golden hour of trauma, prehospital interventions can be critically important. In the USA, having a regionalized, streamlined, emergency medical system to transport trauma patients to the appropriate centers has been shown to decrease mortality [24]. We have evidence from our own experience in Malawi that rapid, direct transfers to KCH yield a survival benefit [25]. Additionally, prehospital treatment protocols for TBI in the USA have demonstrated a decrease in mortality in this population by 50% [26–28]. An analysis of prehospital systems in LMICs demonstrated that the presence of a prehospital system reduced mortality by 25% [29].

Some developing countries that have instituted prehospital programs have noted improvements in trauma care. In Brazil, investigators discovered that the triage of severely injured patients to tertiary centers increased after institution of a prehospital trauma program [30]. In Rwanda, data-driven quality improvement led to enhancement of the prehospital trauma process [31]. Even simple implementations like giving basic first aid training to commercial drivers in Ghana have been shown to improve prehospital care [32].

Over time, the USA has altered its focus from individual trauma programs to building trauma networks. States with more hospitals participating in trauma care at any trauma level designation have better outcomes than states that are less inclusive in their trauma care [33]. The hospitals in Malawi operate in relative isolation to one another and have minimal collaboration with the district centers. In nations like Malawi with finite capital, sharing resources and distributing the trauma load could improve outcomes.

According to the World Health Organization (WHO) trauma maturity score, Malawi has an immature system without cohesive networks or coordination of resources [34]. However, the lack of resources does not mean that improvement cannot be achieved. In South Africa, standardization of data collection has led to elucidation of trauma patterns, which in turn has produced injury control and public health initiatives [35]. In Thailand, implementation of a trauma audit system identified issues in resuscitation practices and led to a decrease in trauma mortality [36]. Peer-review preventable death panels in Pakistan and Iran are leading to similar discoveries of potential correctable deficiencies. Simple quality improvement enactments like regular trauma case review at KCH would be a first step toward change [37].

The limitations of this study are those inherent to any investigation using population data and retrospective methodology. We cannot establish true causality, and we cannot account for all potential confounders, particularly given the paucity of information available regarding patient comorbidities. Given the resources and quality of radiographic data at KCH, determining primary and secondary anatomic injuries was challenging. Of note, 41.5% of Kampala Trauma Scores were missing; however, we attempted account for this by using inverse probability of missing weights, which assumes that lack of a Kampala Trauma Score is stratified missing at random instead of missing completely at random (i.e., as in a complete-case analysis) and allows us to include all observations in our adjusted analyses. In spite of these limitations, the findings were consistent with what we anticipated.

Conclusions

Our investigation revealed that traumatic head injuries are the most common anatomic injuries and pedestrians struck by vehicles are the most common mechanisms associated with prehospital mortality in this population. The resource deficits, underlying laws, and infrastructure of Malawi likely contribute to the patterns of injury seen. While KCH has taken the initial steps toward maturing its trauma system by developing tools to prospectively collect trauma data, the next step is to use that data to incite change. Future interventions in Malawi should focus on a multifaceted approach to upgrade public policy, the built environment, quality improvement, and prehospital management of the trauma patient. The creation of a trauma system with emphasis on prehospital management is imperative if we are to attenuate prehospital trauma mortality.

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