Diurnal variation in trauma mortality in sub-Saharan Africa: A proxy for health care system maturity

Jared R. Gallaher[a], Carlos. Varela[b], Laura N. Purcell[b], Rebecca Maine[a,b], Anthony Charles[a,*]

[a] Department of Surgery, University of North Carolina School of Medicine, Chapel Hill, NC, USA
[b] Department of Surgery, Kamuzu Central Hospital, Lilongwe, Malawi

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ABSTRACT

Background: Globally, traumatic injury is a leading cause of morbidity and mortality in low-income countries. However, trauma centers in these environments have limited resources to manage complex trauma with minimal staffing and diagnostic tools. These limitations may be exacerbated at night. We hypothesized that there is an increase in trauma-associated mortality for patients presenting during nighttime hours.

Methods: We conducted a retrospective analysis of all patients recorded in the Kamuzu Central Hospital trauma registry in Lilongwe, Malawi from January 2012 through December 2016. Nighttime was defined as 18:00 until 5:59. Patients brought in dead were excluded. A modified Poisson regression model was used to calculate the relationship between presentation at night and mortality, adjusted for significant confounders.

Results: 74,500 patients were included. During the day, crude mortality was 0.8% compared to 1.4% at night ($p < 0.001$). The risk ratio of mortality following night time presentation compared to day was 1.90 (95% CI 1.48, 2.42) when adjusted for injury severity, assessed by the Malawi Trauma Score (MTS), and transfer status. When stratified by the year of traumatic injury, the risk ratio of death decreased each year from 2012–2014 but increased in 2015. There was no difference in 2016.

Conclusions: We report the first description of diurnal variation in trauma-associated mortality in sub-Saharan Africa. Injured patients who presented at night had nearly twice the adjusted risk ratio of death compared to patients that presented during the daytime although there were yearly differences. Diurnal variation in trauma-associated mortality is a simple but important indicator of the maturity of a trauma system and should be tracked for health care system improvement.

Introduction

Traumatic injury is a global epidemic that drives the world's burden of surgical disease. Injury contributes greatly to global morbidity and mortality, particularly in low- and middle-income countries (LMICs) where the absence of a developed trauma and health care system further complicates efforts at attenuating the sequalae of injury [1–5]. Well-developed trauma systems integrate prehospital care and transport, patient transfer to hospitals capable of delivering definitive trauma care, and post-discharge rehabilitation. In most resource-poor settings, prehospital and post-discharge care is lacking or nonexistent. Currently, public health efforts emphasize tertiary care centers as the hub of definitive trauma management. These centers should have the capability to provide around the clock, comprehensive care including intensive care units (ICUs), advanced diagnostics, operating rooms, and specialist care such as neuro or orthopedic surgery.

As the timing, severity, and magnitude of traumatic injury presentation is unpredictable, the need for twenty-four hour readiness for trauma care delivery adds to the complexities of system development. Trauma systems must be staffed continuously and with appropriately distributed resources to meet variation in patient volumes. Even in environments with adequate resources, failure to plan for the varied trauma demand can expose system deficiencies. These deficits are most apparent at night when fewer health care personnel, often with less experience, are available [6]. In addition, fewer institutional resources, such as access to

* Corresponding author: School of Medicine University of North Carolina 4008 Burnett Womack Building CB 7228, USA.

E-mail address: anthchar@med.unc.edu (A. Charles).

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diagnostic adjuncts or functioning operating theaters, may be available after hours.

In resource-poor environments, a lack of a mature health care system magnifies these problems [7,8]. At the extremes, this could create two standards of care for trauma management, one during the day and one during the night. In this regard, we sought to better characterize this potential diurnal variation in trauma outcomes at our tertiary center in Lilongwe, Malawi by examining the difference in mortality between patients that presented during the daytime hours compared to those who presented at night time.

Materials and methods

This study is a retrospective analysis of data from the Kamuzu Central Hospital (KCH) Trauma Registry. KCH is a public 900-bed tertiary care hospital in the capital city of Lilongwe, which serves as a referral center for approximately 6 million people in the central region of Malawi. KCH is equipped with six intensive care unit (ICU) beds and six ventilators and a surgical step-down unit with four staffed beds. Trauma and orthopedic surgical services are available seven days a week. Surgical consultants, Malawian general surgery and orthopedic registrars, clinical officers, and rotating general interns staff the trauma service.

The KCH Trauma Registry was established in 2008 in conjunction with the Malawi Ministry of Health to collect patient demographic information, clinical characteristics, and outcome data of all patients who present to the emergency department with traumatic injuries. Trauma registry staff collect and record data twenty-hours a day, seven days a week. Specifically, data points utilized in this study include age, sex, date of injury, setting of injury, mechanism of injury, type and location of injury, vital signs, and outcome (discharge or death). All patients who presented to the emergency department with traumatic injuries during the period of January 2012 through December 2016, were included in this study. We excluded patients who were declared dead on arrival to our center.

The primary aim of this study was to define the relationship between trauma-associated mortality and presentation to KCH during nighttime hours as compared to daytime hours. The primary outcome was all-cause inpatient mortality among trauma patients who presented to the KCH emergency department compared to patients who survived to discharge. We also assessed short-term mortality by examining patients who died within the first 48 h compared to patients who survived past 48 h. The exposure, night time arrival, was defined as the hours between 18:00 and 05:59 based on the day/night cycle in southeast Africa and staffing practices at KCH.

We initially examined the baseline characteristics of the study population, comparing those patients across the years of the study. To identify potential confounders of the relationship between evaluation year and death, we examined the distribution of independent variables, comparing means between groups for the continuous variables, or percentages for the categorical variables. Bivariate analysis for the relationship between each of the independent variables and the outcome was performed using Chi-squared tests for the categorical variables, and 2-sample t-tests for continuous variables. Medians of non-normally distributed continuous variables were tested using a Kruskal–Wallis test. When comparing categorical variables with more than two categories, the aggregate of the remaining categories was used as the referent for comparison. Means are reported with standard deviations and medians with inter-quartile ranges (IQR). Overall crude mortality was calculated using any deaths in the study population, against all other included patients.

We utilized a modified Poisson regression model to estimate the risk ratio for trauma-associated mortality for patients who presented during nighttime hours compared to patients who presented during daytime hours, adjusted for confounders [9,10]. After fitting the initial model with mortality and all potential confounders, we used a change-in-effect method to remove covariates that did not substantially alter the relationship between the time of presentation and mortality. In addition, we tested for interaction in the model. An unadjusted and adjusted risk ratio and 95% confidence interval is reported from the estimates of the final model. Transfer status was considered as a potential confounder and the model was stratified by trauma year based on previously published data from our population during the study period [11,12]. The Malawi Trauma Score (MTS) was used for the determination of injury severity. MTS is a score that ranges from 0–32 based on age, sex, anatomic injury location, presenting mental status, and the presence or absence of a radial pulse on physical examination [13]. A similar modeling strategy was used for reported subset analysis.

All statistical analysis was performed using Stata/SE 13.1 (StataCorp LP, College Station, TX). The Malawi National Health Services Review Committee and University Institutional Review Board and approved this study.

Results

Over the study period, 74,500 patients with traumatic injuries presented to KCH with 51,491 (69.1%) patients presenting during daytime and 23,009 (30.9%) patients presenting at nighttime. (Table 1). This included both patients who were admitted and those who were discharged home from the emergency department. Patients who presented during the day were younger with a median age of 22 years (IQR 8–32) compared to 26 years (IQR 16–34, $p < 0.001$) for night presentations. There were also fewer males during the day at 71.0% ($n = 36{,}562$) versus 75.7% ($n = 17{,}412$, $p < 0.001$) at night. The setting of injury was also different at night in contrast to the daytime. Less than a third of patients who presented during daytime hours were involved in road associated injuries (30.8%, $n = 15{,}844$) compared to almost half at night (48.4%, $n = 11{,}128$, $p < 0.001$). In addition, injuries that occurred at home were more common during the day at 47.9% ($n = 24{,}679$) compared to 34.7% ($n = 7979$, $p < 0.001$) during nighttime.

Injury characteristics

The mechanism of injury also varied between the patient who presented during the day and at night. Motor vehicle collision (MVC) associated injuries were common during both day and nighttime presentation. Patients presenting as the driver or passenger of a MVC were slightly less common during the day at 16.9% ($n = 8702$) while at night, the proportion of patients was 21.3% ($n = 4909$, $p < 0.001$). Pedestrians hit by vehicles were less common during the day than at night, 7.6% ($n = 3917$) and 9.5% ($n = 2175$) respectively ($p < 0.001$). Falls were much more common during the daytime at 32.5% ($n = 16{,}721$) compared to 17.8% ($n = 4097$, $p < 0.001$), while assaults were more common at nighttime, 19.0% ($n = 9770$) vs. 34.6% ($n = 7965$, $p < 0.001$).

The means of arriving at KCH differed greatly between day and night. During the daytime hours, a majority of patients were transported via minibus at 57.7% ($n = 29{,}721$) while this was uncommon at night at 13.1% ($n = 3058$, $p < 0.001$). At night, most patients, 60.1% ($n = 13{,}835$), were brought to the emergency department via private vehicle, while this was only the case for 20.1% ($n = 10{,}349$, $p < 0.001$) of patients during the day. Ambulance service use was uncommon during both day and nighttime hours but was slightly more common at night at 9.6% ($n = 4921$) and 15.1% ($n = 3480$, $p < 0.001$), respectively. The number of patients who were transferred from a lower tier hospital was slightly higher

Table 1
Characteristics of patients presenting at daytime compared to nighttime.

	Daytime patients($n=51{,}491$, 69.1%)	Nighttime patients($n=23{,}009$, 30.9%)	p value
Patient age (years)			
Median (IQR)	22 (8–32)	26 (16–34)	<0.001
Gender: N (%)			
Female	14,921 (29.0)	5588 (24.3)	<0.001
Male	36,562 (71.0)	17,412 (75.7)	
Missing	8 (0.0)	9 (0.0)	
Setting of injury: N (%)			
Home	24,679 (47.9)	7979 (34.7)	<0.001
Work	4,51 (8.8)	1324 (5.8)	
Road/Street	15,844 (30.8)	11,128 (48.4)	
Public space	2338 (4.5)	1094 (4.8)	
Other	3911 (7.6)	1402 (6.1)	
Missing	207 (0.4)	82 (0.4)	
Mechanism of injury: N (%)			
Pedestrian hit by vehicle	3917 (7.6)	2175 (9.5)	<0.001
Driver/passenger in vehicle accident	8702 (16.9)	4909 (21.3)	
Fall	16,721 (32.5)	4097 (17.8)	
Assault	9770 (19.0)	7965 (34.6)	
Collapsed Structure	2961 (5.8)	726 (3.2)	
Other	9014 (17.5)	3013 (13.1)	
Missing	406 (0.8)	124 (0.5)	
Transport to hospital			
Minibus	30,460 (59.1)	3003 (13.1)	<0.001
Private vehicle	10,349 (20.1)	13,835 (60.1)	
Ambulance	4921 (9.6)	3480 (15.1)	
Walked	2295 (4.5)	180 (0.8)	
Police	1057 (2.1)	1643 (7.1)	
Other	2187 (4.3)	656 (2.9)	
Missing	252 (0.5)	212 (0.9)	
Primary injury type: N (%)			
Soft tissue injury	29,721 (57.7)	16,192 (70.4)	<0.001
Fracture	8995 (17.5)	3058 (13.3)	
Dislocation	2962 (5.8)	220 (1.0)	
Traumatic brain injury	1736 (3.4)	1190 (5.2)	
Penetrating wound	1711 (3.3)	471 (2.1)	
Burn	2548 (5.0)	896 (3.9)	
Other	3706 (7.2)	870 (3.8)	
Missing	112 (0.2)	112 (0.5)	
Primary injury location: N (%)			
Head/face	12,835 (24.9)	9322 (40.5)	<0.001
Spine	2649 (5.1)	1172 (5.1)	
Upper extremity	11,247 (21.8)	3447 (15.0)	
Hand	6691 (13.0)	2201 (9.6)	
Chest	2381 (4.6)	1190 (5.2)	
Abdomen/Flank	1702 (3.3)	817 (3.6)	
Pelvis	1096 (2.1)	464 (2.0)	
Lower extremity	12,659 (24.6)	4241 (18.4)	
Missing	231 (0.5)	155 (0.7)	
Malawi trauma score (MTS)			
Mean (SD)	7.9 (2.7)	8.5 (2.8)	<0.001

during the day at 20.1% ($n=10{,}330$) compared to 16.9% ($n=3886$, $p < 0.001$) at night. Among patients that were transferred, ambulance use was much lower during the day at 43.3% ($n=4453$) versus 79.9% ($n=3084$, $p<0.001$) at night. Concurrently, the use of minibus for transfer for these patients was much higher during the day at 40.3% ($n=4149$) versus 4.9% ($n=190$, $p<0.001$) at night.

Soft tissue injuries were overwhelmingly the most common injury type at 57.7% ($n=29{,}721$) during the day and 70.4% ($n=16{,}192$, $p<0.001$) at night. Fractures were slightly more common during the day at 17.5% ($n=8995$) versus 13.3% ($n=3058$, $p<0.001$) at night. Dislocations, head injuries, penetrating wounds, and burns were all less than 5% of all injuries in both groups. The most substantial difference was in traumatic brain injuries which occurred in 3.4% ($n=1736$) of patients during daytime and 5.2% ($n=1190$, $p<0.001$) of patients at nighttime. In terms of primary injury location, injuries to the head or face were common in both groups but much were more frequent in the nighttime group at 24.9% ($n=12{,}835$) and 40.5% ($n=9322$, $p<0.001$), respectively. Both upper and lower extremity injuries were more common in the daytime group with 21.8% ($n=11{,}247$) of patients presenting with an upper extremity injury compared to 15.0% ($n=3447$, $p<0.001$) at night. Lower extremity injuries was seen in 24.6% ($n=12{,}659$) of patients during the day and 18.4% ($n=4241$, $p<0.001$) at night. Injuries to the spine, chest, abdomen/flank, and pelvis were all less common and relatively similar between the two groups, each comprising 5% or less of total injuries. Injury severity was slightly higher at night with mean MTS scores of 7.9 (SD 2.7) during daytime and 8.6 (SD 2.8, $p<0.001$) during nighttime.

Patient disposition

The vast majority of patients were treated and discharged from the emergency department but this proportion was greater during the day at 85.2% ($n=43{,}889$) versus 77.8% ($n=17{,}902$, $p<0.001$) at night. (Table 2) Consequently the percent of patients admitted to the ward at night was higher at 21.2% ($n=4872$, $p<0.001$) compared to only 14.3% ($n=7350$) of patients who presented in the

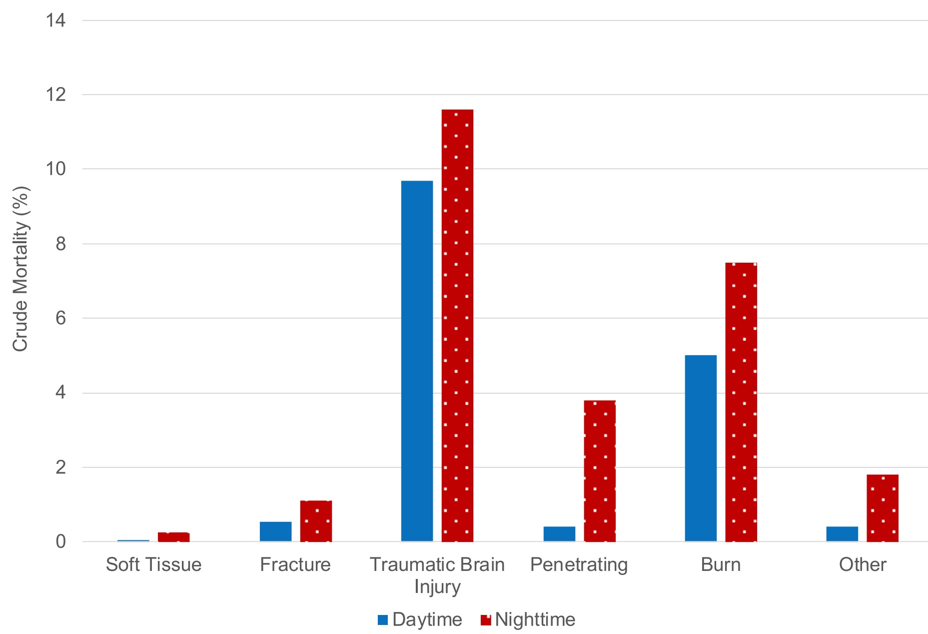

Fig 1. Injury specific mortality stratified by daytime and nighttime.

day. ICU admissions were not common in either group, but also more frequent at night, 0.2% ($n = 108$) compared to 0.5% ($n = 11$, $p < 0.001$) during nighttime hours. While overall ED mortality was very low, it was higher at night, 0.5% ($n = 116$, $p < 0.001$), than in the day, 0.2% ($n = 124$).

Patient outcomes

Overall crude mortality was nearly double at night with daytime mortality at 0.8% and nighttime mortality at 1.4% ($p < 0.001$). Crude mortality within the first 48 h was 0.2% during the day and 0.5% during nighttime hours (< 0.001). Injury-specific mortality was significantly higher at night for some injury types. These differences were most notable for burn injury (5.0% vs. 7.5%, $p = 0.006$) and penetrating injury (0.4 vs. 3.8%, $p < 0.001$). Traumatic brain injury was very high for both groups but was statistically similar (9.7% vs. 11.6%, $p = 0.11$). (Fig. 1) For all patients, the unadjusted risk ratio of death for patients who presented at night compared to daytime was RR 1.80 (95% CI 1.56, 2.10, $p < 0.001$). After controlling for pertinent covariates including transfer status and injury severity as measured using the MTS, the adjusted risk ratio of death for patients presenting at night compared to daytime was RR 1.90 (95% CI 1.48, 2.42, $p < 0.001$). We further stratified adjusted risk ratios by the year of traumatic injury as shown in Table 2. In general, the adjusted risk ratio of death at night decreased each year, except for 2015 (RR 2.61 95% CI 1.52, 4.48) and there was no difference in risk adjusted mortality at night during 2016 (RR 0.97 95% CI 0.62, 1.50). When using this model with only deaths that occurred within 48 h after presentation, the adjusted risk ratio for death for patients presenting at night compared to daytime was RR 1.97 (95% CI 1.26, 3.08, $p = 0.003$).

The difference in adjusted predicted mortality between day and night presentations by MTS is demonstrated in Fig. 2, adjusted for transfer status. The adjusted difference in trauma-associated mortality by MTS, during day versus nighttime, is notable from a score of approximately 18 to 32 where the probability of mortality begins to substantially increase. At a MTS of 20, the predicted mortality of a trauma patient presenting during the day is 6.6% (95% CI 4.9, 8.8) while it is 11.1% (95% CI 8.4, 14.6) at night. This difference in the probability of mortality, adjusted for transfer status, at

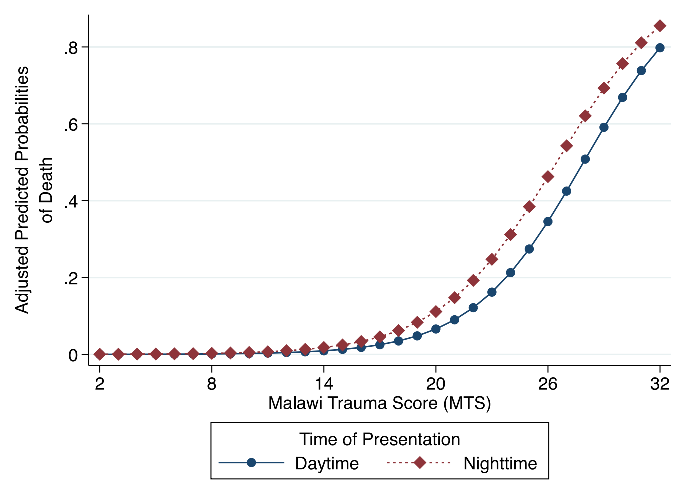

Fig 2. The adjusted predicted probability of death by Malawi Trauma Score (MTS) stratified by daytime and nighttime using logistic regression, adjusted for transfer status.

a MTS of 20 persists when stratified by year except in 2016, largely due to an increase in the daytime predicted probability of death. (Fig. 3)

Mortality was similar between patients who presented on a weekday night versus those on the weekend night. Crude mortality was 1.4% ($n = 221$) on weekdays versus 1.2% ($n = 91$, $p = 0.4$) on weekends. The risk ratio of death for those presenting on a weekend night was not different from those presenting on a weekday night with an adjusted risk ratio of 0.81 (95% CI 0.57, 1.16, $p = 0.3$), adjusted for MTS and transfer status. When examining all patients, either presenting at day or at night, there was still no difference in mortality between those who arrived on a weekday versus a weekend. Among all patients, weekday crude mortality was 1.0% ($n = 503$) compared to 0.8% ($n = 196$, $p = 0.3$) on weekends.

Discussion

This study represents, to the best of our knowledge, the first description of diurnal variation in trauma-associated mortality in

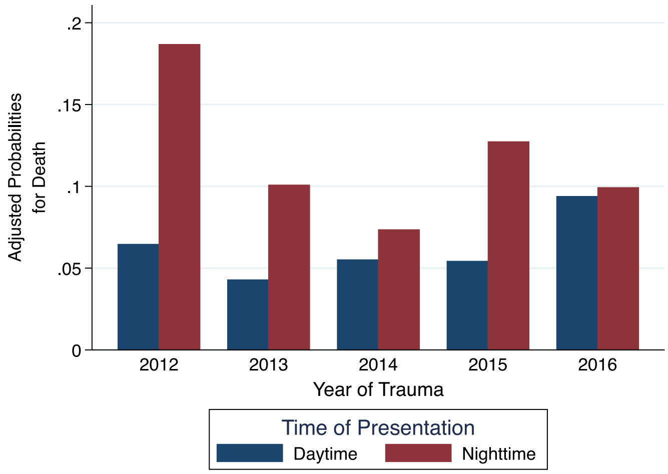

Fig 3. The adjusted predicted probability of death at a MTS of 20 using logistic regression, stratified by daytime and nighttime, adjusted for transfer status.

sub-Saharan Africa. Injured patients who presented during nighttime hours had nearly double the risk ratio of death compared to patients who presented during the daytime even after adjusting for injury severity. This increased mortality risk was present across several different injury types, most notably penetrating and burn injury. There is also a temporal effect of this risk each year, possibly representing changes in staff availability, training improvements, and economic effects on hospital resources.

In a developed trauma system, resource distribution should match the needs of patients, regardless of the time of day they present [14]. Some evidence from high-income countries suggests that mature trauma systems provide equivalent care both during the day and night [15–17]. Notably, each of these studies reflect care at a single high-volume tertiary trauma center functioning within a mature system in a high-resource environment. In contrast, data from more heterogeneous patient populations in other high-income countries demonstrate increased mortality at night compared to the day. A large cohort of Italian hospitals, which included both Level 1 trauma centers and small regional hospitals, showed an increase of nearly 50% in the odds ratio of death for trauma patients presenting at night compared to those presenting during the day. The effect was even greater for patients who transferred from another facility, a finding similar to our study [18]. A large nationwide study in the United States demonstrated an increased adjusted risk of death at night among all levels of trauma centers, although the effect was much greater at lower-level trauma centers [6].

The difference in mortality between daytime and nighttime in our population can be attributed to the lack of a mature regional trauma system, beginning with our tertiary center. The resource limitations that limit delivery of surgical care across sub-Saharan Africa in general are greater at night and likely drive the diurnal variation in mortality seen in this study. Across sub-Saharan Africa a lack of provider staffing is especially problematic in the management of the critically injured and likely contributed to the increased mortality observed at night. Over the last decade, data clearly demonstrated that there is a substantial shortage of healthcare providers, particularly in surgery and anesthesia [19,20]. In addition to general surgeons, surgical subspecialists such as neurosurgeons are rarely available outside of tertiary hospitals and their low numbers, even in urban areas, lead to a paucity of nighttime availability. Furthermore, nurse to patient ratios, already low in the day, tend to be lower at night which decreases patient monitoring in an already overcrowded hospital setting. These types of provider shortages at every level of skill are even worse in district hospitals which are understaffed even during the day [8,21]. Consequently, investment in provider training is critical for improving patient outcomes. We previously demonstrated that a residency training program can improve trauma-associated mortality in environments like Malawi's and the small improvements in diurnal variation during the study may be related to this described phenomenom [11]. Using lay-providers for certain tasks, such as vital sign acquisition, is also effective and may be helpful in austere environments [22].

Our results showing diurnal variation in trauma-related mortality may also reflect the diurnal availability of hospital services. This is particularly evident when emergent care is needed as seen following injury. Minimal, if any, laboratory testing or diagnostic radiology services are performed outside of normal business hours [23]. Blood banking services experience chronic shortages, which actually may have worsened in recent years. The limited supply of blood and increased delays in accessing blood at night hinder trauma resuscitations and may also contribute to increased nighttime trauma mortality, especially in the first 24 to 48 h [24]. In our setting, there is only one operating theater functional after hours and all surgical services, (trauma, general surgery and obstetrics and gynecology) must share this theatre that is allocated on a first come first serve basis and less by surgical acuity. Operating room availability with emergency anesthesia support is also critical for trauma management. We previously showed the structural challenges of scheduling elective cases at our center [25]. These barriers, which also apply to emergency cases, are typically worse during off hours. Improved access to hospital resources at night could improve both early and late mortality from injuries at our center by improving the initial resuscitation. Fluctuations in hospital resource availability are also subject to economic and institutional forces as evidenced by the yearly variation in nighttime mortality in our study. While the risk ratio of death at night compared to the daytime decreased steadily from 2012–2014, there was an increase in risk during 2015 and 2016, concomitant with worsening economic pressures on the health care system in Malawi [26].

Outside of tertiary centers, trauma care in Malawi suffers from near-absent pre-hospital care, especially in rural areas. Previous data from sub-Saharan Africa has shown substantial shortages in pre-hospital care throughout the region with few ambulance services and even fewer trained first-responders [27,28]. Ambulance use was uncommon for our patients who arrived both day and night at our center with a high use of minibuses instead. Training minibus drivers and fare collectors in basic first aid could improve trauma outcomes overall, as recent improvement projects from other regions have focused on first responder programs targeting laypersons such as taxi drivers [29–31]. Identifying other first responders to address first aid needs for patients transported at night, as more formal pre-hospital program are developed, is important. These endeavors are feasible and have shown promise while larger scale projects from other LMICs have even demonstrated a mortality benefit in building prehospital infrastructure [32].

A tenant of improving a national surgical system is to measure the system's performance and the quality of care delivered. In 2015, the Lancet Commission for Global Surgery introduced six core key indicators to assess this capacity [33]. These include access to timely surgery, specialists workforce density, surgical case volume, perioperative mortality, and protection against both impoverishing and catastrophic expenditures for surgical care. Unfortunately, the data required to accurately measure these indicators are often very difficult to obtain in countries like Malawi, where system-level data are absent or of poor quality. Consequently, focusing on trauma indicators may be an alternative to system-level data, given that trauma is the greatest driver of global surgical mortality and morbidity. A health care system built on a platform to provide optimal care to critically injured patients will have the capacity to deliver care to any surgical patient, at any time of day.

Metrics assessing trauma care should include process and outcomes evaluation of pre-hospital, in-hospital and post-discharge care [34]. Diurnal variation in trauma mortality has potential as one of these metrics, serving as a proxy for systematic deficiencies, especially for in-hospital clinical outcomes. It is also simple to calculate from any trauma registry that records basic injury information and clinical outcomes. When national data is limited, this indicator, along with other novel indicators such as the ratio of emergency to elective surgery, can be readily calculated at tertiary care centers and provide trackable data [35].

Conclusion

We report the first description of diurnal variation in trauma-associated mortality in sub-Saharan Africa. Injured patients who presented at night had nearly twice the adjusted risk ratio of death compared to patients that presented during the daytime although there were yearly differences. Diurnal variation in trauma-associated mortality is a simple but important indicator of the maturity of a trauma system and should be tracked for health care system improvement.

Declaration of Competing Interest

The authors have no conflict of interest to disclose. The authors have no financial relationships to disclose.

Data Presented at

This data was presented as an oral presentation at the American College of Surgeons (ACS) Annual Scientific Forum in Boston, MA on October 23, 2018.

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