



# Reallocation of Hospital Resources During COVID-19 Pandemic and Effect on Trauma Outcomes in a Resource-Limited Setting

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Accepted: 5 June 2022 / Published online: 26 June 2022

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## Abstract

**Background** The COVID-19 pandemic has caused unprecedented disruptions to surgical care worldwide, particularly in low-resource countries. We sought to characterize the association between pre-and intra-pandemic trauma clinical outcomes at a busy tertiary hospital in Malawi.

**Methods** We analyzed trauma patients that presented to Kamuzu Central Hospital in Lilongwe, Malawi, from 2011 through July 2021. Burn patients were excluded. We compared patients based on whether they presented before or during the pandemic (defined as starting March 11, 2020, the date of the official WHO designation). We used logistic regression modeling to estimate the adjusted odds ratio of death based on presentation.

**Results** A total of 137,867 patients presented during the study period, with 13,526 patients during the pandemic. During the pandemic, patients were more likely to be older (mean 28 vs. 25 years,  $p < 0.001$ ), male (79 vs. 74%,  $p < 0.001$ ), and suffer a traumatic brain injury (TBI) as their primary injury (9.7 vs. 4.9%,  $p < 0.001$ ). Crude trauma-associated mortality was higher during the pandemic at 3.7% vs. 2.1% ( $p < 0.001$ ). The odds ratio of mortality during the pandemic compared to pre-pandemic presentation was 1.28 (95% CI 1.06, 1.53) adjusted for age, sex, initial AVPU score, transfer status, injury type, and mechanism.

**Conclusions** During the pandemic, adjusted trauma-associated mortality significantly increased at a tertiary trauma center in a low-resource setting despite decreasing patient volume. Further research is urgently needed to prepare for future pandemics. Potential targets for improvement include improving pre-hospital care and transportation, planning for intensive care utilization, and addressing nursing shortages.

## Introduction

Despite modest global health investment, traumatic injury remains a significant source of morbidity and mortality worldwide. Low- and middle-income countries (LMICs)

are especially vulnerable and suffer disproportionately relative to high-income countries [1, 2]. LMICs lack mature trauma systems and the capacity to manage high acuity trauma patients, even at average patient volume. These deficiencies span all aspects of trauma care delivery, including pre-hospital care, adequate transportation between critical access hospitals and tertiary centers, and access to needed operative intervention and intensive care unit (ICU) beds. When there are acute changes in patient volume or shifts in hospital resources, there is often a substantial strain on available resources to treat injured patients.

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The COVID-19 pandemic introduced unprecedented global hospital resource pressure, even in the most developed healthcare systems. This led to significant increases in excess mortality, both from COVID-19-associated deaths and the unintended consequences on other aspects of healthcare delivery [3–6]. Trauma services experienced decreased patient volume due to regional lockdowns but with variable clinical outcomes compared to the pre-pandemic period [7–11]. In areas with high COVID-19 patient burden, trauma services were impacted by delays in care due to overwhelmed transportation, full emergency departments, personal protective equipment (PPE) shortages, and reappropriation of surgical ICU beds for COVID-19 patients [12].

While evidence from sub-Saharan Africa (SSA) has shown a decrease in general healthcare utilization during the pandemic, such as hospital admissions and outpatient visits, there is a paucity of data on the effect on surgical services [13–15]. Given the limited surgical resources available in many countries throughout SSA, the pandemic may have exacerbated barriers to trauma surgical care for many patients [16]. Limited data from South Africa have shown reductions in orthopedic services and decreased patient evaluations for injury at major tertiary centers, but without an analysis of the associated patient outcomes [17–19]. Consequently, this study sought to examine pandemic patterns in trauma presentation and the associated clinical outcomes of patients presenting pre-pandemic compared to patients presenting during the intra-pandemic period at a busy, tertiary trauma center in a resource-limited environment in SSA.

## Materials and methods

We performed a retrospective analysis of the Kamuzu Central Hospital (KCH) Trauma Registry. This registry was established in 2008 and prospectively collects data on all trauma patients evaluated at KCH, a public 900-bed tertiary care hospital in Lilongwe, the capital city of Malawi [20]. KCH has a catchment area of over six million people in central Malawi. The hospital has five intensive care beds with ventilators and a fully staffed general and orthopedic surgery staff.

The KCH Trauma Registry captures demographic, clinical, and outcome data on all patients that present to the emergency department after injury. Registry staff is available to collect data twenty-four hours a day, seven days a week. We used the Alert, Voice, Pain, Unresponsive (AVPU) Scale, which records a patient's consciousness level as either alert, responding to verbal stimuli, responding to painful stimuli, or unresponsive. It is simple to record and correlates with GCS (Glasgow Coma Scale)

[21]. All patients who presented to the emergency department with traumatic injuries from January 2011 through July 2021 were included in this study except for patients with primary burn injuries, who were excluded.

Our primary aim was to test the hypothesis that trauma-associated mortality increased at KCH during the COVID-19 pandemic. The primary outcome was crude, in-hospital mortality for trauma patients. We defined the COVID-19 intra-pandemic period as the time starting on March 11, 2020, when the WHO declared it an international pandemic through the end of the study period [22]. No data were collected in April or May 2020 due to strict lock-down in Malawi. The number of surgery staff remained constant during the study period.

We initially compared patients based on whether they presented before or during the COVID-19 pandemic. We compared patient characteristics, including demographic and clinical data. Our bivariate analysis included Chi-squared tests for the categorical variables, Fischer's exact test for binary variables, and 2-sample t-tests for continuous variables. Means were reported with 95% confidence intervals. Crude mortality was calculated using the in-hospital deaths in the study cohort.

We used a logistic regression model to estimate the odds ratio for trauma-associated mortality for patients who presented before or during the COVID-19 pandemic, adjusted for confounders. We initially ran an unadjusted model with crude mortality. We initially fit the model with crude mortality and potential confounders identified in our bivariate analysis for our adjusted analysis. We then used a change-in-effect methodology, removing potential confounders if they did not significantly change the relationship (< 10% change) between pandemic presentation and mortality. Odds ratios are reported with a 95% confidence interval. We also used a logistic regression model to graph the differences in the adjusted predicted probability of mortality based on the increasing age of the patient.

All statistical analysis was performed using Stata/SE 17.0 (Stata- Corp LP, College Station, TX). The Malawi National Health Services Review Committee and the University of North Carolina Institutional Review Board approved this study.

## Results

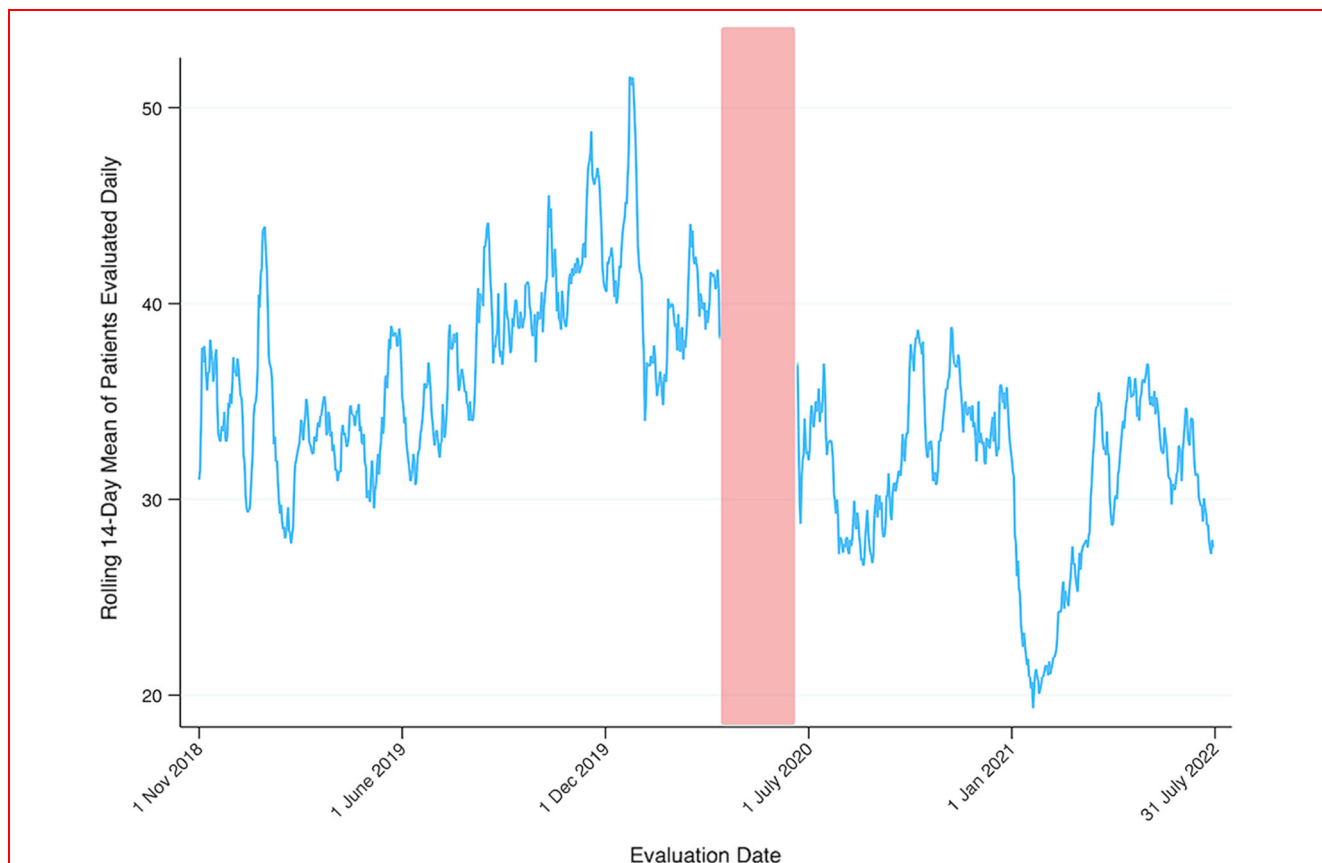
From January 2011 through July 2021, 137,867 trauma patients presented to KCH and were recorded in the trauma registry. Of these patients, 124,438 patients presented before the pandemic, and 13,526 patients arrived during the pandemic. Pre-pandemic, the mean daily number of trauma patients evaluated in the emergency room was significantly higher at 37.0 patients (95% CI 36.7, 37.4) compared to a

mean of 31.3 (95% CI 30.4, 32.2) patients during the pandemic, leading to a mean difference of 5.8 patients a day (95% CI 4.6, 6.9,  $p < 0.001$ ). These differences are shown in Fig. 1, which plots the rolling 14-day mean daily number of patients evaluated from the period of November 2018 through July 2021. The red shaded area signals the period when no patients were recorded due to strict lockdown.

A comparison of baseline characteristics of patients presenting pre-pandemic or during the pandemic is shown in Table 1. During the pandemic, patients were more likely to be older (mean age 24.9 vs. 28.0 years,  $p < 0.001$ ) and male (74.0 vs. 79.0%,  $p < 0.001$ ). Patients were also more likely to be struck by a vehicle (8.9 vs. 12.4%) or be the driver/passenger in a motor vehicle collision (21.9% vs. 30.5%,  $p < 0.001$ ) compared to the pre-pandemic period. There was a significant increase in the proportion of patients that were transferred to KCH during the pandemic (19.0% vs. 30.5%,  $p < 0.001$ ), with an increase in the mean time to transfer at 2.8 days compared to 3.9 days ( $p < 0.001$ ) during the pandemic. Transportation to the hospital shifted significantly away from public mini-bus

(41.0 vs. 25.5%) use to private vehicles (38.5 vs. 49.1%) and ambulances (11.4 vs. 17.5%,  $p < 0.001$ ). In terms of injury, there were proportional increases in fractures (17.1% vs. 20.4%) and traumatic brain injuries (TBI) (4.9% vs. 9.7%,  $p < 0.001$ ) with patients more commonly presenting with multi-system injuries (31.7% vs. 38.3%,  $p < 0.001$ ). In parallel with an increase in TBIs during the pandemic, almost twice as many patients arrived at the emergency department unresponsive (1.4% vs. 2.2%,  $p < 0.001$ ).

During the pandemic, a much higher proportion of patients were admitted to the hospital at 25.0% ( $n = 3,351/13,526$ ) compared to 16.2% ( $n = 20,173/124,438$ ) in the pre-pandemic period ( $p < 0.001$ ) (Table 2) However, despite a higher proportion of patients, admitted to the hospital, the proportion of patients admitted to the ICU was similar at only 0.3% ( $n = 408/124,438$ ) pre-pandemic and 0.4% ( $n = 48/3,351$ ,  $p = 0.6$ ) during the pandemic. The use of operative intervention was also significantly higher during the pandemic, with 4.1% of patients undergoing an operation pre-pandemic and 8.2% during ( $p < 0.001$ ). This equated to a mean number of operative cases of 46 cases



**Fig. 1** The rolling 14-day mean number of patients evaluated from November 1, 2018, through July 13, 2022. The red bar signifies the first two months of the pandemic when no data were collected

**Table 1** Characteristics of patients presenting before and during the COVID-19 pandemic

	Pre-pandemic ( <i>n</i> = 124,438)	Pandemic ( <i>n</i> = 13,526)	<i>p</i> value
<i>Patient age (years)</i>			
Mean (95% CI)	24.9 (24.8, 25.0)	28.0 (27.8, 28.3)	< 0.001
<i>Gender: N (%)</i>			
Female	32,337 (26.0)	2834 (21.0)	< 0.001
Male	92,045 (74.0)	10,639 (79.0)	
<i>Mechanism of injury: N (%)</i>			
Pedestrian hit by vehicle	10,920 (8.9)	1567 (12.4)	< 0.001
Driver/passenger in vehicle accident	26,806 (21.9)	3864 (30.5)	
Fall	33,501 (27.4)	2543 (20.1)	
Assault	30,538 (25.0)	2921 (23.1)	
Collapsed structure	6269 (5.1)	478 (3.8)	
Other	14,301 (11.7)	1288 (10.2)	
<i>Transferred?</i>			
Yes	23,593 (19.0)	4117 (30.5)	< 0.001
<i>Transfer time from injury</i>			
Days: Mean (95% CI)	2.8 (2.7, 3.0)	3.9 (3.2, 4.6)	0.002
<i>Transportation to hospital: N (%)</i>			
Mini-bus	50,371 (41.0)	3272 (25.5)	< 0.001
Private vehicle	47,390 (38.6)	6314 (49.1)	
Ambulance	14,005 (11.4)	2248 (17.5)	
Police transport	5573 (4.5)	582 (4.5)	
Walked	3726 (3.0)	218 (1.7)	
Other	1725 (1.4)	214 (1.7)	
<i>Primary injury type: N (%)</i>			
Soft tissue injury	78,709 (63.6)	7441 (55.6)	< 0.001
Fracture	21,159 (17.1)	2728 (20.4)	
Dislocation	5013 (4.1)	308 (2.3)	
Traumatic brain injury	6125 (4.9)	1297 (9.7)	
Penetrating wound	4299 (3.5)	473 (3.5)	
Other	8451 (6.8)	1145 (8.5)	
<i>Multi-system trauma</i>			
Yes: <i>N (%)</i>	39,203 (31.7)	5130 (38.3)	< 0.001
<i>Initial AVPU</i>			
Alert	121,269 (98.0)	13,129 (97.2)	< 0.001
Responds to voice	133 (0.1)	19 (0.1)	
Responds to pain	511 (0.4)	56 (0.4)	
Unresponsive	1789 (1.4)	300 (2.2)	

per month pre-pandemic compared to 65 cases per month during the pandemic.

Crude in-hospital mortality was 2.1% (2,653/124,438) pre-pandemic and 3.7% (497/13,526,  $p < 0.001$ ) during the pandemic. This included an increase in the proportion of patients that were declared dead in the emergency department after evaluation at 1.3% (1,603/124,438) and 2.2% (296/13,526,  $p < 0.001$ ) before and during the pandemic, respectively. Using logistic regression, the unadjusted odds

ratio of in-hospital mortality if a patient presented during the COVID-19 pandemic compared to pre-pandemic presentation was OR 1.76 (95% CI 1.59, 1.94). When adjusting for initial AVPU score, sex, age, injury type, and transfer status, the adjusted OR of mortality was 1.45 (95% CI 1.22, 1.71). When patients that were declared dead upon arrival at the emergency department were excluded from the analysis, the effect of the pandemic was similar. With these deaths excluded, the unadjusted OR was 1.80 (95%

**Table 2** Clinical outcomes of patients presenting before and during the COVID-19 pandemic

	Pre-pandemic ( <i>n</i> = 124,438)	Pandemic ( <i>n</i> = 13,526)	<i>p</i> value
<i>Admitted?</i>			
Yes	20,173 (16.2)	3351 (25.0)	< 0.001
<i>ICU admission?</i>			
Yes	408 (0.3)	48 (0.4)	0.6
<i>Underwent procedure in operating room</i>			
Yes	5067 (4.1)	1109 (8.2)	< 0.001
<i>Death declared in emergency department?</i>			
Yes	1603 (1.3)	296 (2.2)	< 0.001
<i>Crude in-hospital mortality</i>			
Died	2653 (2.1)	497 (3.7)	< 0.001

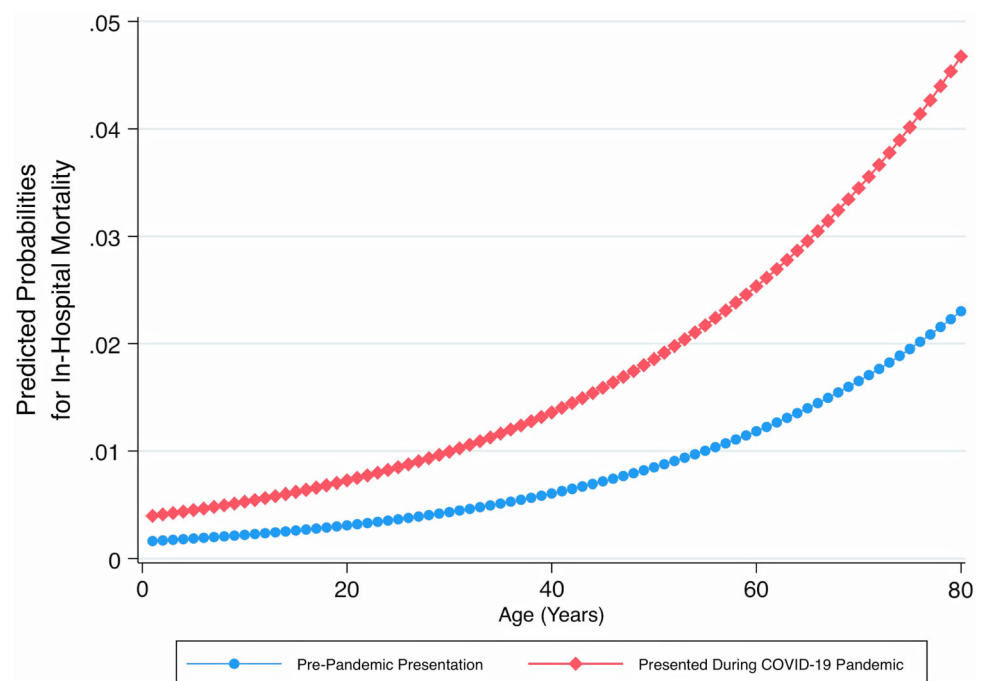
CI 1.54, 2.09). When adjusting for the initial AVPU score, sex, age, injury type, mechanism, and transfer status again, the adjusted OR was 1.27 (95% CI 1.06, 1.53). Lastly, we graphed the differences in the predicted mortality based on presentation during the pandemic against increasing patient age, adjusted for initial AVPU score, sex, injury type, and transfer status (Fig. 2).

### Ten-year trends

Trends over the last ten years in patient characteristics, interventions, and outcomes can be seen in Table 3. Notably, the number of patients was markedly decreased in 2020 and 2021 during the pandemic, as previously

discussed. The mean age increased during the study period, consistent with previous reports from Malawi showing that the proportion of elderly trauma patients was increasing [23]. In 2011, the mean age was 23.4 (SD 15.3) years and increased to 28.0 years (SD 15.3,  $p < 0.001$ ) in 2021 and 2022. The proportion of patients involved in a motor vehicle accident, either as a driver/passenger or as a pedestrian also increased over time and was significantly higher during the pandemic. While the number of patients was relatively stable, the number of patients presenting as a transfer increased each year from 12.7% in 2011 to 22.5% in 2019 prior to the pandemic. It then increased dramatically in 2021 and 2022 during the pandemic at 28.2% and 30.5% ( $p < 0.001$ ), respectively. Pre-pandemic, the

**Fig. 2** The adjusted, predicted probability of in-hospital death by age, comparing the pre-pandemic period and the time during the pandemic



**Table 3** Trends of patient characteristics over the study period. 2021 includes January through July

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021 (Jan-July)	p value
Number of patients evaluated	13,880	14,823	15,597	15,352	13,688	12,153	11,470	11,227	13,535	9977	6165	
<i>Patient age (years)</i>												
Mean (SD)	23.4 (15.3)	23.7 (15.8)	23.7 (15.8)	23.7 (15.9)	24.5 (15.9)	26.0 (15.7)	25.7 (15.7)	26.6 (15.7)	27.1 (15.5)	28.0 (15.4)	28.0 (15.3)	< 0.001
<i>Sex: N (%)</i>												
Male	10,055 (72.5)	10,674 (72.0)	11,387 (73.0)	11,194 (72.9)	10,077 (73.7)	9127 (75.1)	8506 (74.3)	8453 (75.3)	10,447 (77.2)	7783 (78.3)	4905 (79.8)	< 0.001
Female	3815 (27.5)	4144 (28.0)	4208 (27.0)	4155 (27.1)	3601 (26.3)	3020 (24.9)	2946 (25.7)	2774 (24.7)	3086 (22.8)	2163 (21.7)	1238 (20.2)	
<i>Mechanism of injury: N (%)</i>												
Pedestrian hit by vehicle	490 (3.6)	1187 (8.0)	1309 (8.4)	1318 (8.7)	1190 (8.8)	1289 (10.8)	1186 (10.5)	1258 (11.5)	1481 (11.6)	1049 (11.3)	723 (12.5)	< 0.001
Driver/passenger in vehicle accident	3185 (23.3)	2516 (17.0)	2701 (17.4)	2886 (19.0)	2779 (20.5)	2851 (23.8)	2765 (24.5)	2931 (26.7)	3553 (27.7)	2662 (28.7)	1816 (31.4)	
Fall	4315 (31.5)	4725 (32.0)	4693 (30.2)	4716 (31.0)	3876 (28.5)	2741 (22.9)	2860 (25.3)	2375 (21.6)	2669 (20.8)	1850 (19.9)	1199 (20.7)	
Assault	3523 (25.7)	3703 (25.0)	3974 (25.6)	3775 (24.8)	3384 (24.9)	3180 (26.6)	2713 (24.0)	2664 (24.3)	2985 (23.3)	2259 (24.3)	1278 (22.1)	
Collapsed structure	838 (6.1)	829 (5.6)	824 (5.3)	696 (4.6)	689 (5.1)	516 (4.3)	560 (5.0)	506 (4.6)	638 (5.0)	452 (4.9)	195 (3.4)	
Other	1337 (9.8)	1824 (12.3)	2017 (13.0)	1826 (12.0)	1666 (12.3)	1378 (11.5)	1214 (10.7)	1237 (11.3)	1489 (11.6)	1012 (10.9)	581 (10.0)	
<i>Transferred? N (%)</i>												
Yes	1763 (12.7)	2194 (14.8)	2796 (17.9)	2949 (19.2)	2640 (19.3)	2689 (22.1)	2346 (20.5)	2589 (23.2)	3028 (22.5)	2809 (28.2)	1873 (30.5)	< 0.001
<i>Admitted? N (%)</i>												
Yes	2598 (18.8)	2625 (17.7)	2461 (15.8)	2220 (14.5)	1826 (13.3)	1947 (16.0)	1562 (13.6)	2011 (18.1)	2478 (18.5)	2236 (22.6)	1534 (25.1)	< 0.001
<i>Underwent Surgery, n (%)</i>												
Yes	179 (1.3)	1058 (7.1)	647 (4.1)	544 (3.5)	442 (3.2)	468 (3.9)	269 (2.3)	582 (5.2)	752 (5.6)	762 (7.6)	468 (7.6)	< 0.001
<i>Mortality, n (%)</i>												
Crude in-hospital mortality	221 (1.6)	237 (1.6)	257 (1.6)	244 (1.6)	270 (2.0)	309 (2.5)	341 (3.0)	323 (2.9)	368 (2.7)	369 (3.7)	205 (3.3)	< 0.001

number of patients admitted varied each year but was greater than 1,800 every year except in 2017 ( $n = 1,562$ ), when the hospital was undergoing significant renovations. Lastly, crude in-hospital mortality trended up during the study period. It was 1.6% in 2011 and 2.7% in 2019, before the pandemic. This increased significantly to 3.7% in 2021 and 3.3% in 2022 ( $p < 0.001$ ).

## Discussion

This study is the first description, to our knowledge, of trauma-associated outcomes from SSA during the COVID-19 pandemic. Patient volume decreased significantly during the pandemic but with a concomitant increase in trauma severity, with patients presenting with worse initial vital signs and a higher proportion of multi-system trauma and traumatic brain injury. Trauma patients had higher mortality during the pandemic despite lower volumes and greater operating room capacity, with a nearly 50% increase in the adjusted odds of death. This was true for patients who died early in the emergency department or later after being admitted to the hospital.

Unfortunately, data on the pandemic's effect on surgical outcomes from other LMICs are scarce, but the available evidence suggests that surgical services have substantially decreased during COVID-19. A 2021 survey of neurosurgeons in 42 African countries revealed that over half of respondents were not performing any elective operations during the pandemic, and they reported dramatic shortages of basic personal protective equipment, including surgical masks (91%) and gloves (85%) [24]. A survey of pediatric surgeons from Nigeria demonstrated similar findings, with over 90% of centers having postponed elective operations early in the pandemic [25]. Outside of SSA, a trauma center in India published comparable findings to ours among patients with a head injury. They found that while patient volume decreased significantly during the pandemic, severe head injury mortality was significantly higher at 59% compared to 47% ( $p = 0.02$ ) pre-pandemic [26].

Based on our study and published data, trauma patients throughout SSA have likely suffered worse clinical outcomes during the pandemic. Previous evidence has documented the significant shortages in surgeons, perioperative clinicians, and infrastructure available to surgical patients in LMICs [27, 28]. As Chu et al. summarize in their review, access to surgical services in SSA was precarious pre-pandemic and consequently was at a significant risk of acutely worsening under COVID-19 related pressures on the healthcare system [16]. In Malawi, this first manifested in changes in pre-hospital transport. Pre-hospital care in Malawi is mainly absent, with most transportation done

through public mini-bus taxis or private vehicles [29]. During the pandemic, the use of mini-buses decreased dramatically, likely due to periods of lockdown and economic changes from the pandemic. The mean time for transportation also increased for transferred patients with a concomitant increase in the proportion of patients who were declared dead after arrival at the emergency department. Given the higher proportion of transferred patients during the pandemic, significant changes in transportation access may have delayed care for patients leading to worse clinical outcomes.

Throughout the pandemic, LMICs also struggled to meet ICU bed demand [30]. Surging demands from critically ill COVID-19 patients exacerbated the global shortage of critical care beds in LMICs. In our study, despite an increase in injury severity during the pandemic, there was no increase in ICU bed utilization compared to the pre-pandemic period. At baseline, KCH has limited critical care resources, affecting severely injured trauma patients, including those with a head injury. We previously demonstrated that limited critical care services hinder TBI management at KCH, leading to high TBI-associated mortality [31]. This includes a lack of monitored beds, limited ventilators, and inadequate nursing. The shift in these services to COVID-19 patients may explain our study's observed increase in adjusted mortality. In contrast, access to the operating room appeared to increase during the pandemic, with the proportion of patients undergoing an operation doubling. As seen globally, cancellation of elective operations likely improved operating room access for some patients with emergencies [32]. However, this increase in the number of operations did not improve clinical outcomes, further suggesting that a lack of critical care services contributed substantially to worse patient outcomes.

Mitigating the strain on trauma services in a low-resource environment during an event like COVID-19 is exceptionally challenging. Published strategies for preserving surgical services in SSA during the pandemic have focused on strategic resource allocation for essential operations, conserving PPE needed for safe operations, protecting surgical staff from COVID-19 infection, and expanding critical staff [33, 34]. Unfortunately, most of these require significant resources in an already underfunded and underdeveloped healthcare system. For example, keeping adequate PPE stocked was a challenge at KCH pre-pandemic, before the need for these supplies increased exponentially. In addition, while the number of surgeons available at KCH has increased substantially over the last ten years due to a government-sponsored training program, nursing shortages remain a problem throughout the region [35–37]. In hospitals with limited technological capability for patient monitoring, having enough nurses to monitor

and care for critically ill patients is vital. As countries in SSA prepare for future pandemics, there must be a plan to protect surgical services, especially essential services like trauma surgery, given its high contribution to global morbidity and mortality. These improvements should include targeting pre-hospital care, critical care capacity, and investment in the nursing workforce.

This study is limited by its retrospective design and ability to only analyze patients presenting to KCH. Consequently, patients who died before transport at the scene of their injury or district hospitals cannot be included. We have tried to mitigate this bias by reporting outcomes for patients who were declared dead in the emergency department and analyzing crude in-hospital mortality. We have also adjusted for injury severity when possible including variables that contribute to severity such as injury type, mechanism, and presenting mental status. We also acknowledge that we do not have data on the cause of death which could provide addition insight into pandemic-related effects on trauma management. Despite these limitations, KCH presents a unique opportunity to analyze the effects of the pandemic due to its large catchment area in central Malawi and the high volume of trauma patients evaluated there.

## Conclusion

During the pandemic, adjusted trauma-associated mortality significantly increased at a tertiary trauma center in a low-resource setting despite decreasing patient volume. Further research is urgently needed to prepare for future pandemics. Potential targets for improvement include improving pre-hospital care and transportation, strategic planning for intensive care utilization, and addressing nursing shortages.

**Acknowledgements** None.

**Author contributions** JRG contributed to this paper by: design of study, acquisition, analysis, and interpretation of data, drafting and revision of the manuscript, and statistical analysis. AY contributed to this paper: design of study, interpretation of data, critical drafting and revision of the manuscript. CK contributed to this paper by: data acquisition, design of study, critical revision of the manuscript for important intellectual content, and administrative and technical support. AS contributed to this paper by: design of study, statistical analysis, and critical revision of the manuscript for important intellectual content. LP contributed to this paper by: data acquisition, design of the study, revision of the manuscript for important intellectual content. AGC contributed to this paper by: conception and design of the study, acquisition, analysis, and interpretation of data, drafting and revision of the manuscript, statistical analysis, obtaining of funding, and supervision.

**Funding** Provided by the Department of Surgery at the University of North Carolina.

**Data availability** Jared R. Gallaher, MD, MPH and Anthony G. Charles, MD, MPH had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

## Declarations

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

**Ethical approval** IRB: The Malawi National Health Services Review Committee and the University of North Carolina Institutional Review Board approved this study.

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