

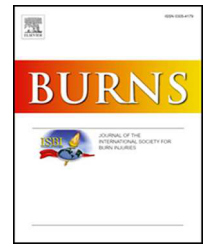


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# The effect of COVID-19 on burn management and outcomes in a resource-limited setting

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## ABSTRACT

**Introduction:** Optimal burn care includes fluid resuscitation and early excision and grafting. During the COVID-19 pandemic, resource-constrained environments were susceptible to interruptions in burn care. We sought to characterize pre- and intra-pandemic burn-associated outcomes at a busy tertiary hospital in Malawi.

**Methods:** This is a retrospective analysis of burn patients that presented to Kamuzu Central Hospital Lilongwe from 2011 through December 2021. We compared patients based on whether they presented pre- or intra-pandemic, starting on March 11, 2020, the date of official WHO designation. Comparing these cohorts, we used modified Poisson modeling to estimate the adjusted risk of undergoing an operation and the risk of death.

**Results:** We included 2969 patients, with 390 presenting during the pandemic. Patient factors were similar between the cohorts. More patients underwent surgery pre-pandemic (21.1 vs 10.3 %,  $p < 0.001$ ) but crude mortality was similar at 17.3 % vs. 21.2 % ( $p = 0.08$ ). The RR of undergoing surgery during the pandemic was 0.45 (95 % CI 0.32, 0.64) adjusted for age, sex, % TBSA, flame burns, and time to presentation. During the pandemic, the risk ratio for in-hospital mortality was 1.23 (95 % CI 1.01, 1.50) adjusted for age, sex, % TBSA, surgical intervention, flame burns, and time to presentation.

**Conclusions:** During the pandemic, the probability of undergoing burn excision or grafting was significantly lower for patients, independent of the severity. Consequently, the adjusted risk of mortality was higher. To improve patient outcomes, efforts to preserve operative capacity for burn patients during periods of severe resource constraint are imperative.

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## 1. Introduction

Burn wounds are potentially devastating injuries leading to long-term disability and death. Current data estimates that over 10 million people suffer burn injury each year, leading to 100,000–200,000 deaths annually [1]. Burn injury is closely

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correlated with lower socioeconomic status in high-income countries (HIC) and low or middle-income countries (LMICs) [2]. Consequently, patients with the least access to comprehensive burn care are the most likely to suffer a burn injury, putting them at a higher risk of a poor outcome. Over 90 % of burn injury deaths and burn-associated disabilities occur in low or middle-income countries (LMICs), with sub-Saharan Africa (SSA) and southeast Asia accounting for over two-thirds of this burden [3]. Burn injury remains an unrecognized global health problem despite the burden of disease, with most health systems in LMICs under-resourced to manage complex burn injury [4].

Unfortunately, the COVID-19 pandemic added additional system-level stress on the care of burn patients, especially in limited-resource environments. Globally, the volume of COVID-19 patients places substantial resource constraints on health care systems, causing indirect effects on the care of patients without COVID-19 [5–8]. Burn care is especially vulnerable to these pressures, given the complexity of providing high-quality burn management. This includes initial resuscitation, close hemodynamic monitoring, daily wound care, early surgical excision and grafting of deeper burn wounds, and physical therapy to prevent contracture. Given the frequency of burn injury in LMICs, providing this level of care is challenging at baseline, even without pandemic pressures [9].

Data from centers in the United States, Europe, and Asia demonstrated that critical care shortages created an austere environment for burn patients during the pandemic [10]. However, minimal evidence on the impact of the pandemic on burn care in sub-Saharan Africa is available. A recent survey of 43 burn centers, including 6 in SSA, showed that basic burn supplies were limited in many centers and that a low-income environment was associated with decreased access to burn care during the pandemic [11]. Consequently, this study sought to describe changes in burn management during the pandemic, including access to operative intervention and the effect on burn-associated mortality at a tertiary burn center in a resource-limited environment in SSA.

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## 2. Materials and methods

We performed a retrospective analysis of the Kamuzu Central Hospital (KCH) Burn Registry. The registry records all patients admitted to the KCH Burn Center. Patient data is recorded twenty-four hours a day, seven days a week. Data captured includes patient demographics, clinical data including burn injury characteristics, burn interventions including burn excision and skin grafting, and patient outcomes.

KCH is a public tertiary care hospital in the capital city of Lilongwe and serves the central region of Malawi with a catchment area of at least five million people. The burn unit was established at KCH in 2011 and is equipped with a dedicated burn operating room, 31 beds, and nurses trained in burn care. Clinical officers and a full-time plastic surgeon attend to patients.

We included all patients admitted from July 2011 through December 2021. We defined our exposure as patients

presenting during the COVID-19 pandemic compared to those presenting before COVID-19. We defined the COVID-19 intrapandemic period beginning on March 11, 2020, the day of the WHO declaration, extending through the end of the study period [12]. Our primary aim was to explore whether presentation during the COVID-19 pandemic affected access to the operating room or patient outcomes. Surgical intervention was defined as any procedure performed for a burn injury, including debridement, excision, amputation, or skin grafting. Our primary outcome was crude in-hospital mortality.

We initially compared patients based on presentation relative to the COVID-19 pandemic. We compared demographic characteristics, clinical and operative data, and patient outcomes. We utilized bivariate analysis, using Fischer's exact test for binary variables and Chi-squared tests for the categorical variables. For continuous variables with a normal distribution, we used 2-sample t-tests, and for variables with a non-normal distribution, we used a Kruskal-Wallis test. Means are reported with standard deviations and medians with the inter-quartile range.

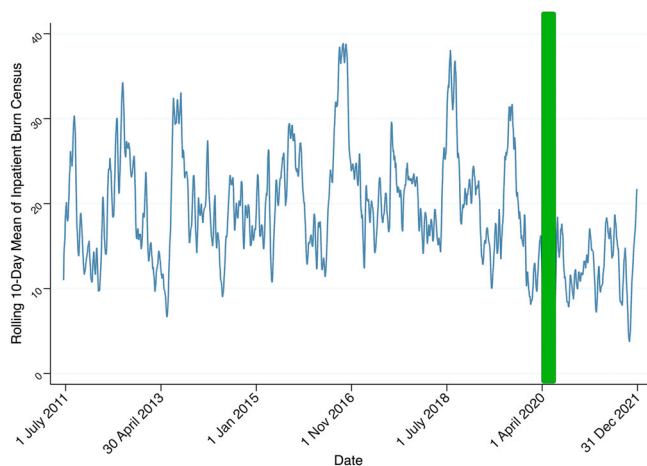
To analyze the relationship between mortality and whether a patient presented during the COVID-19 pandemic or not, we used a modified Poisson model [13,14]. We initially created an unadjusted model with mortality and report this model estimate with a 95 % confidence interval. We then created an adjusted model, initially including potential confounders from our bivariate analysis. Age was treated as a categorical variable based on previous data from our center [15]. Reliable burn depth data is not available, so the presence of a flame burn was used as a surrogate for deeper burns. We then systematically used a change-in-effect methodology, removing potential confounders if they did not significantly change the relationship (< 10 % change) between pandemic presentation and mortality. We repeated this strategy exploring the relationship between pandemic presentation and the use of operative intervention. Lastly, we used a logistic regression model to graph the differences in the adjusted predicted probability of mortality based on pandemic presentation and %TBSA.

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.

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## 3. Results

From June 2011 through December 2021, 2969 patients were admitted to the KCH Burn Unit. The median age was 3 years (IQR 2, 12) for all patients, with a male preponderance (58.2 %,  $n = 1728$ ). Most burns are cooking related (57.9 %,  $n = 1719$ ) with a mean TBSA of 17.1 % (SD 14.0 %). Prior to the pandemic, 2579 patients were admitted to the burn unit, with 390 patients admitted during the pandemic. This equated to a mean daily census of 20.2 (SD 6.5) patients prior to the pandemic and 11.6 (SD 4.7) patients during the pandemic ( $p < 0.001$ ). Fig. 1 shows the changes in the rolling 10-day mean census of the burn unit during the study period.



**Fig. 1 – The rolling 10-day mean number of patients admitted from July 1, 2011, through December 31, 2021. The green bar signifies the first two months of the pandemic when no data was collected.**

Notably, the census has significant seasonal variance and was significantly lower during the pandemic [16]. The green shaded area illustrates the period when no patients were recorded in the registry due to a national lock-down.

Table 1 compares patient characteristics based on whether they presented before or during the pandemic. Age ( $p=0.10$ ) and gender ( $p=0.3$ ) were similar between the two groups. While the proportion of burns caused by flame or scald was similar between the two cohorts, we found a higher prevalence

of cooking-related burn injuries during the pandemic (59.5 % vs. 64.0 %,  $p=0.006$ ). The median TBSA was similar at 13.5 % (IQR 8.0, 20.5) pre-pandemic and 14.5 % (IQR 9.0, 22.2,  $p=0.06$ ) intra-pandemic. Most patients in both cohorts presented within twenty-four hours after injury at 67.4 % ( $n=1702$ ) pre-pandemic and 71.1 % ( $n=275$ ,  $p=0.2$ ) intra-pandemic. Notably, the use of a traditional healer prior to presentation at KCH decreased significantly during the pandemic, at 9.9 % ( $n=244$ ) and 0.8 % ( $n=3$ ,  $p<0.001$ ), respectively.

The differences in management based on pandemic presentation are demonstrated in Table 2. Significantly more patients were prescribed antibiotics at admission during the pandemic compared to the pre-pandemic period (55.1 % vs. 74.9 %,  $p<0.001$ ). However, a much smaller proportion of patients underwent surgery for their burn injury during the pandemic (21.1 % vs. 10.3 %,  $p<0.001$ ). The median time to operation was not significantly different, with both groups having a median of over 11 days from admission. Crude mortality was also not statistically different at 17.3 % pre-pandemic and 21.2 % ( $p=0.08$ ) during the pandemic.

We modeled the risk of undergoing operative intervention and in-hospital mortality associated with presentation during the COVID-19 pandemic using modified Poisson regression. (Table 3) Presentation during the pandemic was associated with a RR of 0.49 (95 % CI 0.36, 0.66,  $p<0.001$ ) for undergoing operative intervention. When adjusted for age, sex, %TBSA, flame burns, and time to presentation, the adjusted RR of undergoing operative intervention was 0.48 (95 % CI 0.34, 0.68,  $p<0.001$ ). Analysis of clinical outcomes demonstrated that presentation during the pandemic was

**Table 1 – A comparison of patient characteristics based on whether they presented before or during the COVID-19 pandemic.**

	Pre-Pandemic (n = 2579)	Pandemic (n = 390)	p value
<b>Patient Age (years)</b>			
Median (IQR)	3.0 (2.0–12.0)	4.0 (0.0–18.0)	0.10
<b>Gender: N (%)</b>			
Female	1083 (42.1 %)	153 (39.2 %)	0.3
Male	1491 (57.9 %)	237 (60.8 %)	
<b>Type of Injury: N (%)</b>			
Scald	1576 (61.5 %)	251 (64.9 %)	< 0.001
Flame	937 (36.6 %)	128 (33.1 %)	
Other	50 (2.0 %)	8 (2.1 %)	
<b>Burn Cause</b>			
Cooking Related	1475 (59.5 %)	244 (64.0 %)	0.006
Clothes Caught Fire	318 (12.8 %)	22 (5.8 %)	
Fell into Flame	433 (17.5 %)	63 (16.5 %)	
House Fire	51 (2.1 %)	12 (3.1 %)	
Explosion	40 (1.6 %)	8 (2.1 %)	
Mob Justice	15 (0.6 %)	4 (1.0 %)	
Electric	33 (1.3 %)	5 (1.3 %)	
Other	113 (4.6 %)	23 (6.0 %)	
<b>%Total Burn Surface Area (TBSA)</b>			
Median (IQR)	13.5 (8.0–20.5)	14.5 (9.0–22.2)	0.056
<b>Time to Presentation: N (%)</b>			
0–24 h	1702 (67.4 %)	275 (71.1 %)	
24–48 h	115 (4.6 %)	20 (5.2 %)	
> 48 h	709 (28.1 %)	92 (23.8 %)	
<b>Was Traditional Medicine Used?</b>			
Yes: N (%)	244 (9.9 %)	3 (0.8 %)	< 0.001

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

	Pre-Pandemic (n = 124,438)	Pandemic (n = 13,526)	p value
Were Antibiotics Prescribed at Admission?			
Yes: N (%)	1422 (55.1 %)	292 (74.9 %)	< 0.001
Underwent Surgery for Burn Injury?			
Yes: N (%)	543 (21.1 %)	40 (10.3 %)	< 0.001
Time to Operating Room from Admission (Days)			
Median (IQR)	16.0 (7.0, 31.0)	11.5 (5.0, 22.0)	0.08
Crude In-Hospital Mortality			
Died	442 (17.3 %)	72 (21.2 %)	0.08

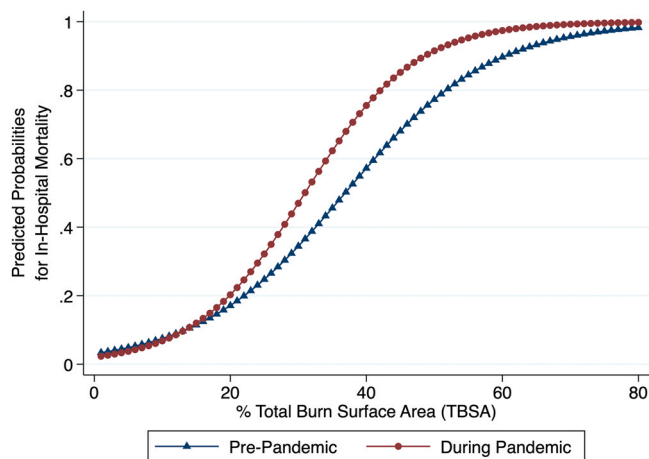
**Table 3 – Relative risk for undergoing operative intervention or dying based on presentation during the pandemic. The adjusted model for undergoing operative intervention was adjusted for age, sex, % total burn surface area (TBSA), flame burns, and time to presentation. The adjusted model for death was adjusted for age, sex, % TBSA, surgical intervention, flame burns, and time to presentation.**

Intervention or Outcome		p value
	<b>Unadjusted RR Associated with Pandemic Presentation (95 % CI)</b>	
Undergoing Operative Intervention	0.49 (0.36, 0.66)	< 0.001
Death	1.22 (0.98, 1.53)	0.08
	<b>Adjusted RR Associated with Pandemic Presentation (95 % CI)</b>	
Undergoing Operative Intervention	0.48 (0.34, 0.68)	< 0.001
Death	1.23 (1.01, 1.50)	0.043

associated with a RR of mortality of 1.22 (95 % CI 0.98, 1.53,  $p = 0.08$ ). When adjusted for age, sex, surgical intervention for a burn injury, % TBSA, flame burns, and time to presentation, the adjusted RR was 1.23 (95 % CI 1.01, 1.50,  $p = 0.043$ ). We then used the same model parameters in a logistic regression model to graph the differences in adjusted predicted probability, stratified by a presentation before or during the pandemic. Fig. 2 shows the adjusted predicted probability of in-hospital mortality against %TBSA.

#### 4. Discussion

This study reports an increase in the risk of burn-associated mortality during the COVID-19 pandemic at a busy tertiary



**Fig. 2 – The adjusted, predicted probability of in-hospital death by % total burn surface area (TBSA), comparing the pre-pandemic period and the time during the pandemic.**

burn center in SSA. While the patient census decreased by almost 50 % during the pandemic, the use of operative intervention for burn injury also reduced, with only 10 % of patients undergoing surgery. Unfortunately, the adjusted risk of mortality was 23 % higher for patients who presented during the pandemic, even when controlling for decreased utilization of surgical intervention. While COVID-19 has directly caused substantial death globally, the indirect effects on health care delivery in other sectors have led to excess mortality among surgical patients in our resource-limited setting.

There is minimal data on the effect of the COVID-19 pandemic on burn care in SSA. A 2021 global survey from 43 countries demonstrated that most burn centers had maintained burn surgeon availability during the pandemic, particularly in higher-income countries, but that overall capacity for managing burn patients decreased in most regions. Reductions in capacity were directly related to the availability of anesthesiologists, decreasing the availability of early burn excision [11]. This finding correlates with the KCH experience, where the use of burn excision dropped dramatically, despite lower burn patient volumes. While we do not have data on why patients did not undergo surgery, it was undoubtedly multifactorial, including limited anesthesia support due to a national lockdown and staffing shortages. Other factors, including a lack of supplies or operating room staff restrictions, also likely played a role. In addition, the increase in the adjusted risk of death persisted despite controlling for the use of the surgical intervention. Our findings suggest that factors beyond a lack of operating room access contributed to worse clinical outcomes. This may have included inadequate wound care due to supply or staffing shortages, increased infectious complications due to a lack of antibiotics, or even concurrent COVID-19 infections.



Reports from outside of Africa have shown mixed results on pandemic effects and burn care. A survey of 19 public and private burn centers in India showed significant variability in the availability of burn care [17]. However, the authors showed that non-emergency services, including elective operations and rehabilitation, were substantially reduced during the pandemic at most centers. In contrast to our study, data from a tertiary center in New Delhi, India, showed a decrease in admissions to their center but without a change in patient outcomes [18]. Data from HICs such as the United Kingdom and the United States have shown variations in admission patterns but relatively little change in access to operative intervention or patient outcomes [19,20]. The heterogeneity of published reports suggests that regional pandemic factors had a significant effect on burn patient epidemiology and that some burn centers were more prepared than others to address changes in supplies, staffing, or operating room access. For example, at KCH, while fewer patients presented to the hospital during the pandemic with burn injury, burn injury severity was relatively similar in each cohort.

Given our results, it is imperative that burn centers in SSA plan for future pandemics to improve burn patient outcomes. The most important step is preserving operative capacity for burn patients, especially those with more extensive or deeper burns. We previously demonstrated that access to burn excision and grafting decreased mortality for pediatric and adult patients in Malawi [21,22]. Given the strong effect seen previously at KCH and the decrease in the proportion of patients undergoing an operation during the pandemic, this may have contributed to worse patient outcomes. In addition, data from KCH has also shown that early excision (<5 days from presentation) improves in-hospital mortality [23]. While the median time to surgery did not change between the study cohorts, the median remained over 11 days despite decreases in patient volume during the pandemic. Given its relationship with mortality, early excision of large or deep burns should be considered an aspect of emergency services and should not be postponed with elective cases.

However, maintaining the operative capacity for emergencies is complex, requiring pre-pandemic planning and coordination of resources. Barrett et al. found that centers that successfully preserved burn services during the pandemic had successful regionalized planning for resource utilization [10]. These burn centers also effectively conserved resources such as basic medical equipment. Burn care relies heavily on supplies for wound care, personal protective equipment, and surgical intervention. Unfortunately, evidence from SSA suggests that even the most basic surgical supplies have been in short supply throughout the pandemic [24]. Considering the burden of burn injury in SSA and its high association with mortality, burn care must be considered an essential service during future pandemics. Consequently, health systems in LMICs must plan to distribute resources needed for burn care, including basic wound supplies, at the regional level. This necessitates maintaining adequate backup supplies, coordinating operative resources to maximize efficiency, and training an adequate nursing workforce [25,26].

Our study is limited by its retrospective design. As a result, we can only include patients admitted to the KCH burn unit. The pandemic likely affected what patients were able to present to the hospital, biasing the results to only those patients who were able to travel. We have tried to diminish this bias by controlling for factors known to be associated with mortality in this patient population. We can also not describe why fewer burn patients underwent an operation during the pandemic. To contextualize this decrease, we have provided important patient information, such as burn severity, which factor into operating decision-making. Lastly, we do not have information on concurrent COVID-19 infections due to the lack of available testing in Malawi throughout most of the pandemic.

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## 5. Conclusion

During the COVID-19 pandemic, the probability of patients undergoing burn excision or grafting was significantly lower, independent of the severity. Consequently, the adjusted risk of mortality was higher. To improve patient outcomes, efforts to preserve operative capacity for burn patients during periods of severe resource constraint are imperative.

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## CRediT authorship contribution statement

Jared R. Gallaher, MD, MPH, contributed to this paper by the study's design, acquisition, analysis, and interpretation of data, drafting and revision of the manuscript, and statistical analysis; Mustufa Abid, MD, MPH, contributed to this paper: design of the study, interpretation of data, critical drafting, and revision of the manuscript; Linda Kayange, MB,BS, contributed to this paper by data acquisition, design of the study, critical revision of the manuscript for important intellectual content, and administrative and technical support; Laura Purcell, MD, MPH, contributed to this paper by data acquisition, design of the study, revision of the manuscript for important intellectual content; Anthony G. Charles, MD, MPH, contributed to this paper by conception and design of the study, acquisition, analysis, interpretation of data, drafting and revision of the manuscript, statistical analysis, obtaining of funding, and supervision.

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## Declaration of Competing Interest

The authors have no conflict of interest to disclose.

## Acknowledgments

Study data were collected and managed using REDCap electronic data capture tools hosted at UNC. REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, pro-

viding: (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to standard statistical packages and (4) procedures for importing data from external sources.

### Access to data

Jared R. Gallaher, MD, MPH, and Anthony G. Charles, MD, MPH, had full access to all of the data in the study and took responsibility for the data's integrity and the accuracy of the data analysis.

### IRB

The Malawi National Health Services Review Committee and the University of North Carolina Institutional Review Board approved this study.

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