



Original article

Impact of nursing education and a monitoring tool on outcomes in traumatic brain injury



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ABSTRACT

Introduction: Throughout the world, traumatic brain injury (TBI) is one of the leading causes of morbidity and mortality. Low-and middle-income countries experience an especially high burden of TBI. While guidelines for TBI management exist in high income countries, little is known about the optimal management of TBI in low resource settings. Prevention of secondary injuries is feasible in these settings and has potential to improve mortality.

Methods: A pragmatic quasi-experimental study was conducted in the emergency centre (EC) of Mulago National Referral Hospital to evaluate the impact of TBI nursing education and use of a monitoring tool on mortality. Over 24 months, data was collected on 541 patients with moderate (GCS9–13) to severe (GCS ≤ 8) TBI. The primary outcome was in-hospital mortality and secondary outcomes included time to imaging, time to surgical intervention, time to advanced airway, length of stay and number of vital signs recorded.

Results: Data were collected on 286 patients before the intervention and 255 after. Unadjusted mortality was higher in the post-intervention group but appeared to be related to severity of TBI, not the intervention itself. Apart from number of vital signs, secondary outcomes did not differ significantly between groups. In the post-intervention group, vital signs were recorded an average of 2.85 times compared to 0.49 in the pre-intervention group (95% CI 2.08–2.62, $p \leq 0.001$). The median time interval between vital signs in the post-intervention group was 4.5 h (IQR 2.1–10.6).

Conclusion: Monitoring of vital signs in the EC improved with nursing education and use of a monitoring tool, however, there was no detectable impact on mortality. The high mortality among patients with TBI underscores the need for treatment strategies that can be implemented in low resource settings. Promising approaches include improved monitoring, organized trauma systems and protocols with an emphasis on early aggressive care and primary prevention.

African relevance

- Traumatic brain injury (TBI) is common in Uganda and mortality is high
- Best practice in emergency care of TBI in resource limited settings such as Uganda are low
- Close monitoring of vital signs is a low cost intervention that allows early detection of deterioration

Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability worldwide, affecting millions of people every year [1,2]. More than 90% of the morbidity and mortality caused by TBI occurs in low-and middle-income countries (LMICs) [2]. Road traffic injuries (RTIs), falls and interpersonal violence are among the top causes of TBI [2].

In Uganda, 13% of mortality is caused by trauma and RTI ranks as the 11th leading cause of death and disability [3–5]. Half of all Ugandan trauma patients are affected by TBI and the mortality rate in patients with severe TBI approaches 55% [5–8]. Analysis of CRASH trial

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data found that patients with severe TBI in LMICs have more than twice the odds of dying compared to those in high-income countries (HICs) (mortality 51% vs 30%) [17]. This is likely a result of disparities in care [17]. HICs have developed guidelines for TBI that focus on early neuroimaging, timely evacuation of intracranial hemorrhage, close monitoring and intensive care [9]. Optimal management of patients with TBI in low-resource settings is still poorly elucidated [9,18,19]. The WHO essential trauma care guidelines recommend early and appropriate decompression and prevention of secondary brain injury as mainstays of treatment [18]. This can be challenging in Uganda, where access to neurosurgery and computed tomography (CT) is limited.

Since primary brain injury occurs at the time of impact, management of TBI focuses on preventing secondary injuries [9]. Hypotension and hypoxia are especially dangerous and have been shown to increase mortality two- to three-fold [10–13]. Even one episode can significantly worsen outcome and mortality increases exponentially with repeated exposure [9,12,13]. A recent pre-hospital study found an adjusted odds ratio of 6.1 for mortality in TBI when both hypoxia and hypotension were present [10,11,14,15]. Secondary injuries can occur at any time after the primary insult and may go unnoticed if patients are not closely monitored [12,16]. Despite limitations, preventing and managing secondary brain injury in Uganda is feasible and has the potential to improve patient outcomes.

Mulago National Referral Hospital (MNRH), one of Uganda's two national referral hospitals, is located in Kampala and receives 75% of the city's traumas in addition to referrals from the rest of the country. MNRH is one of the only hospitals in the country with neurosurgical services and employs 5 of the country's 9 neurosurgeons. Despite this capacity, monitoring of patients with TBI at MNRH is limited. A recent study noted that only 17% of patients admitted to the neurosurgery unit had vital signs documented on admission [8]. Care for patients with TBI is initiated by clinical officers and nurses who staff the Emergency Centre (EC). EC nurses are responsible for providing medications, monitoring patients and alerting clinical officers to any changes in patient status. Because they are typically the first providers to interact with patients and provide direct care during the initial 24–48 h when patients are at greatest risk for secondary injury, EC nurses are prime candidates to improve outcomes through close monitoring and prevention of secondary injuries. This study seeks to determine whether providing EC nurses with TBI education and a monitoring tool could improve outcomes in patients with moderate to severe TBI at MNRH.

Methods

Setting

MNRH is a 1500-bed national referral and teaching hospital [5] that receives almost 4000 trauma patients in the casualty department of the EC annually, of which 41.6% are admitted [6]. RTI is the most common cause of injury and is responsible for 61% of mortality [6]. Most injuries involve the head, neck or face (44%) [5,6]. These injuries also tend to have the highest mortality rates [5,6]. MNRH is equipped with a 16-slice CT scanner, laboratory and X-ray capabilities, an ultrasound machine and a six to eight bed intensive care unit (ICU) equipped with ventilators. There is also a neurosurgical high dependency unit (HDU) with four to eight beds, continuous monitoring capability, and oxygen tanks but no ventilators [7].

Clinical officers perform the initial evaluation in the EC and write orders for medications, initial diagnostics and perform minor procedures. EC nurses provide medications and care for patients while they await specialty consultation. At the time of this study 30–33 nurses working 8-hour shifts staffed the EC. The number of nurses on shift varies from one to four per shift [21]. Patients typically spend the first 24–48 h, if not longer, in the EC while they await imaging and review by consultants. Intravenous fluids and some analgesics are readily available in the EC, but family or friends must purchase other

medications. The EC has two oxygen tanks that are often shared by multiple patients and there are no ventilators. Surgical residents, anesthesia residents, or the EC attending manage airways. These providers are usually only available during daytime hours.

Study design

This was a prospective, quasi-experimental, pre-post study that took place in the MNRH EC in Kampala, Uganda, between November 2015 and November 2017. Convenience sampling was used to identify patients with moderate (GCS 9–13) and severe (GCS $\leq$ 8) TBI. Data collection forms were placed in qualifying patient's charts and completed by EC nurses (Appendix A).

After completion of the pre-study phase, a nursing educational intervention was implemented based on current Brain Trauma Foundation guidelines and included pathophysiology of secondary injury, clinical assessment and recognition of neurologic deterioration and appropriate treatment of abnormal vital signs. Training was provided to introduce EC nurses to the monitoring tool to be used during assessment of patients with TBI (Appendix B). Education was provided in the form of a Powerpoint lecture lasting 1 h and was conducted by MG and LW. These sessions were offered on multiple occasions to ensure all nurses in the EC had been trained. A refresher course was held 2.5 months into the second phase of the study. Development of the monitoring tool was based on commonly used nursing flowsheets and allowed for two-hourly recording of vital signs and neurologic status as well as any treatments administered. Cut offs for abnormal vital signs were included to act as a prompt for possible intervention. Vital signs to be recorded included blood pressure, heart rate, respiratory rate, and oxygen saturation. Temperature and blood glucose were also included, but were to be monitored every 4 h. Neurologic status was assessed by GCS and pupil size and reactivity. Blood pressure cuffs, pulse oximeters, penlights, thermometers and glucometers with test strips as well as GCS reference cards were supplied to facilitate patient monitoring. In the post-intervention phase, nurses were responsible for identifying patients with moderate to severe TBI, placing the monitoring tool in the patient's chart and reassessing enrolled patients every 2 h.

Patients with moderate and severe TBI $\geq$ 15 years old were included if they arrived to the EC within two days of their initial injury. If a patient's age was unknown but was recorded as 'adult' they were included. Required sample size was determined to be 538, with 269 in each group using an estimated mortality of 25% and 80% power to detect a 10% difference in mortality with a two-sided alpha of 0.05. Primary outcome was all-cause in-hospital mortality. Secondary outcomes included time to neurosurgical intervention, time to CT, time to advanced airway and length of stay. Number of recorded vital signs, time between patient reassessment and location and time of death were also analysed.

Data handling

Trained research assistants collected research forms from the medical chart at the end of the patient's hospital stay. Attempts were made to abstract missing information from patient's charts. De-identified data were uploaded to a secure electronic database and paper forms were secured in a locked box accessible only to the primary investigator (PI) and co-PI.

Analysis

Descriptive statistics were used to compare patient characteristics between groups and *t*-test or chi-squared testing were used to generate *p*-values. Mortality rates pre- and post-intervention were compared using two-sample test of proportions. Median length of stay, time to CT, time to neurosurgical intervention and time to advanced airway were compared between groups using Wilcoxon rank-sum to determine

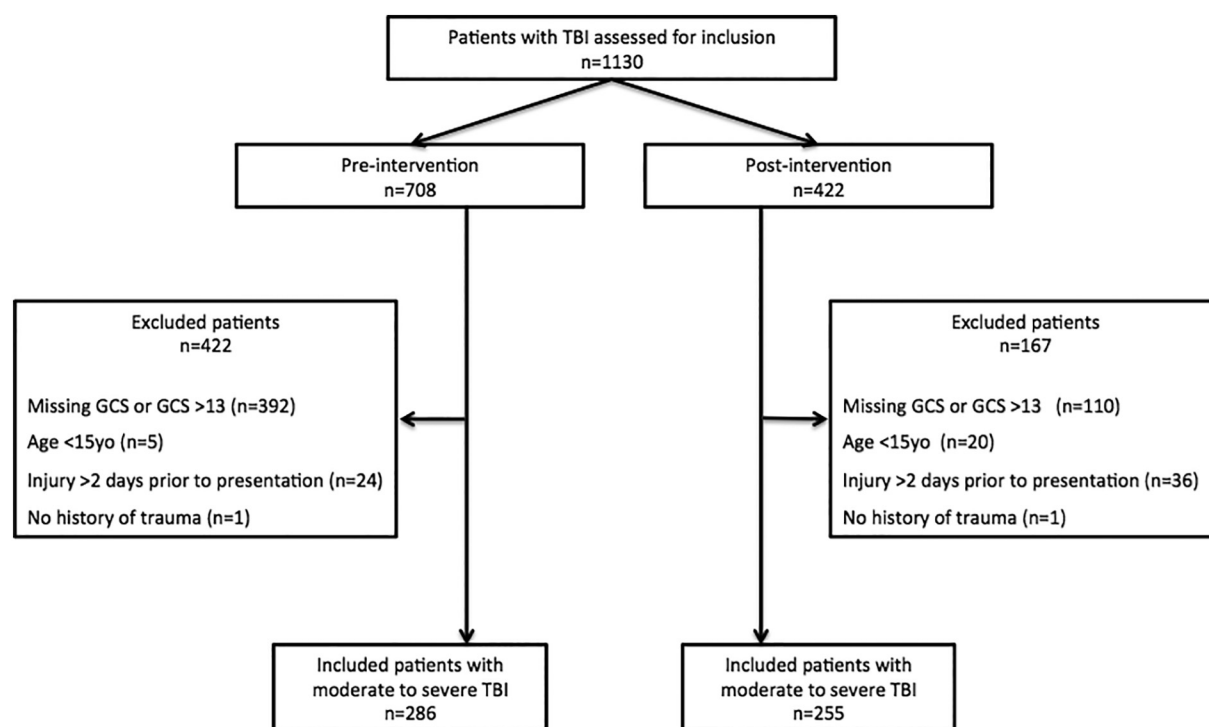


Fig. 1. Patient selection.

Patient characteristics were similar between groups (Table 1). TBI severity was higher in the post-intervention group as measured by lower average GCS. RTI was the primary cause of injury.

significance. Chi-squared and Fischer's exact test were used as appropriate to compare vital signs between groups. Univariate logistic regression was performed to assess relationship between death and various clinical factors. Backward stepwise regression was used to generate a multiple logistic regression model from variables found to be significant on univariate analysis. Case matching based on GCS was performed post-hoc to assess differences in mortality between groups. All data were analysed using Stata 14 SE (StataCorp. 2015. *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP).

Ethical approval

Ethical approval was obtained from the ethical review committees of Makerere University, Mulago Hospital and the London School of Hygiene and Tropical Medicine.

Results

Of 1130 patients with TBI assessed for inclusion, 541 patients (286 pre-intervention, 255 post-intervention) had moderate to severe TBI and met inclusion criteria (Fig. 1). The main reason for patient exclusion in both groups was missing GCS or GCS > 13.

Primary outcome

Overall mortality was higher in the post-intervention group (24% vs 36%, $p = 0.0014$, 95%CI 5%–20%). Given the higher proportion of severe TBI in the post-intervention group, case matching by GCS was performed post-hoc and did not demonstrate any difference in mortality (29.3% vs 31.7%, $p = 0.6$) (Fig. 2).

In both groups, nearly half (45.5% vs 52.9%, $p = 0.36$, 95% CI -0.23–0.09) of TBI related deaths occurred in the first 24 h, most of these in the EC (49.3% vs 71.4%, $p = 0.02$). 19 patients in the post-intervention group died prior to getting a CT compared to only four in the pre-intervention group (7.5% vs 1.4% $p \leq 0.001$, 95% CI

Table 1

Patient characteristics.

	Pre n = 286	Post n = 255	p-Value
Age, y (SD)	30.24 (10.74)	31 (11.43)	0.48
Male (%)	259 (91)	236 (93)	0.3
Severe TBI (%)	71 (25)	117 (46)	< 0.001
Average GCS (SD)	10.05 (2.59)	8.68 (3.09)	< 0.001
CT (%)	201 (70.3)	166 (65)	0.37
Mechanism			
RTA (%)	166 (58)	173 (68)	0.02
Boda	63	77	0.03
Pedestrian	38	30	0.68
Assault (%)	99 (35)	63 (25)	0.012
Fall (%)	9 (3)	10 (4)	0.63
Other (%)	12 (4)	9 (4)	0.69
Neurosurgical procedure ^a (%)	29 (10)	16 (6)	0.1
Advanced airway ^b (%)	18 (6)	18 (7)	0.78

Statistically significant p values are in bold.

^a Craniotomy, hematoma evacuation and drainage, craniectomy.

^b Endotracheal intubation or tracheostomy.

2.6%–9.6%).

Monitoring & vital signs

There was a marked increase in monitoring of patients as a result of the intervention with 141 (49.3%) patients in the pre-intervention group having vitals assessed compared to 251 (98%) in the post-intervention group (Table 3).

Prevalence of secondary injuries was not significantly different between groups, with hypoxia being the most common vital sign abnormality (Table 4). There were more occurrences of combined hypotension and hypoxia in the post-intervention group, but this was not statistically significant.

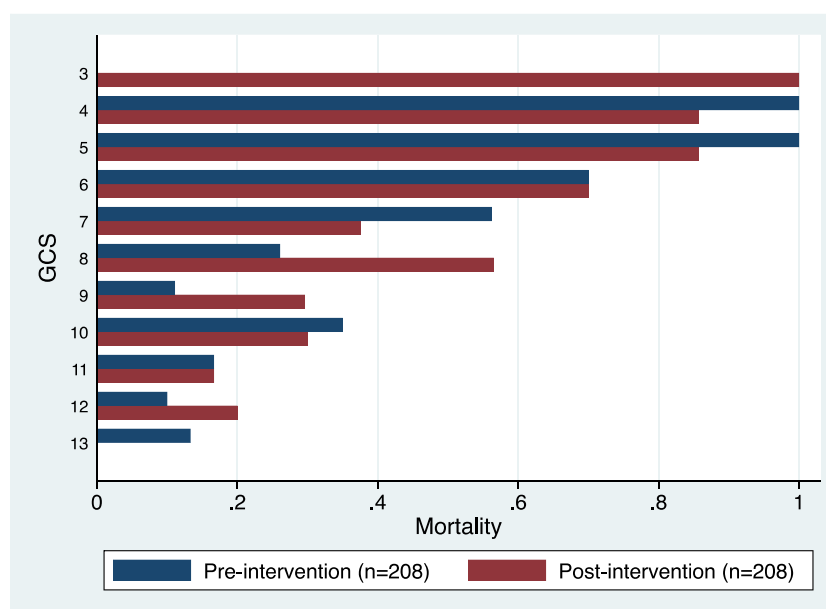


Fig. 2. Mortality by GCS after case matching.

Regression analysis was performed to identify factors associated with mortality. Having a CT scan and a higher GCS had a protective effect (Table 2). Placement of an advanced airway was associated with increased odds of mortality.

Table 2
Multivariate logistic regression.

	OR	p-Value	95% CI
Group	0.98	0.96	0.55–1.77
CT	0.49	0.01	0.29–0.85
Advanced airway	4.98	0.02	1.24–7.21
GCS	0.69	< 0.001	0.62–0.76
Multiply injured	1.99	0.09	0.9–4.41
Vital signs	1.35	0.42	0.65–2.8
Age	1.01	0.265	0.99–1

Statistically significant p values are in bold.

Table 3
Assessment by vital sign.

	Pre ^a	Post	p-Value
	n = 141	n = 251	
Blood pressure	82 (58.2%)	244 (98.8%)	< 0.001
Pulse	118 (83.7%)	249 (99.2%)	< 0.001
Oxygen saturation	46 (32.6%)	232 (93.9%)	< 0.001
Temperature	0	215 (85.7%)	
Glucose	27 (19.1%)	76 (30.3%)	0.016
Respiratory rate	26 (18.4%)	185 (73.7%)	< 0.001

Statistically significant p values are in bold.

^a Only initial vital signs available.

In the post-intervention group vital signs were recorded in the EC an average of 2.85 times per patient compared to 0.49 in the pre-intervention group (95% CI 2.08–2.62, $p < 0.001$). The median time interval between vital signs was 4.5 h (IQR 2.1–10.6) in the post-intervention group.

Secondary outcomes

There were no significant differences in median length of stay (4d vs 4d, $p = 0.054$), time to CT (9.48 h vs 10.97 h, $p = 0.7$), time to neurosurgical intervention (16.27 h vs 18.25 h, $p = 0.75$), or time to advanced airway (34.6 h vs 24.9 h, $p = 0.74$) between groups.

Table 4
Prevalence of secondary injuries.

	Pre % (n/N ^a)	Post % (n/N ^a)	p-Value
Hypoxia	56.5 (26/46)	58.2 (135/232)	0.834
Hypotension	2.4 (2/82)	6.6 (16/244)	0.16
Hypoglycemia	0 (0/27)	5.3 (4/76)	0.22
Hyperglycemia	7.4 (2/27)	6.6 (5/76)	0.88
Hyperthermia	0 (0/0)	20.9 (45/215)	N/A
Hypotension & hypoxia	0 (0/42)	5.7 (13/227)	0.112

Hypoxia = SpO₂ < 94; Hypotension = SBP < 90; Hypoglycemia ≤ 70 mg/dL; Hyperglycemia ≥ 200 mg/dL; Hyperthermia ≥ 38 °C.

^a N = total number of patients assessed for each vital sign.

Discussion

Consistent with previous studies, RTIs were the leading cause of TBI in this population and mostly affected young men [2,5,6,22,23]. A large percentage of RTIs involved pedestrians and Boda-bodas, which are motorcycle taxis, a common form of transportation in Uganda. Boda drivers and passengers are often unhelmeted, making them more susceptible to TBI [24,25].

Mortality

Despite the success of our intervention on nursing care, we were unable to detect any benefit on mortality. While monitoring vital signs is important, the frequency of reassessment as well as treatment of abnormal parameters may have been inadequate. Additionally, impact on mortality may have been overshadowed by other factors such as severity of injury, limited access to ventilators or delays along the continuum of care. Hospital renovations may have also negatively impacted our results, as access to ICU, HDU and CT were limited during this time.

While unadjusted mortality was higher in the post-intervention group, after case matching to adjust for severity of injury there was no difference between groups. Patients with lower GCS and those requiring advanced airway placement had an increased likelihood of death. These factors are reflective of severity of injury, which could explain their

association with mortality.

A retrospective chart review of patients with severe TBI at Mulago from 2008 to 2009 found a mortality rate of 25.8%, which is significantly lower than our estimated mortality of 59.5% in this cohort [7]. Some of this variation may be attributed to differences in inclusion criteria as well as the retrospective nature of the study [7]. While the mortality among patients with severe TBI in our study is much higher than previously noted, it is consistent with a more recent Ugandan study that found a 55% mortality rate. Estimates from other African countries are similar. Patients with severe TBI admitted to ICUs in Nigeria and Kenya had mortality rates of 52.2% and 54% respectively [33,34]. A study conducted in Tanzania by Staton et al. included patients in the EC and found a mortality of 47% among patients with severe TBI [26]. In Rwanda, patients with severe TBI had a slightly higher mortality of 56.1% [29].

Most deaths occurred early while patients were still in the EC. This highlights the importance of focusing on the early post-injury time period and suggests more resources should be available for early detection, treatment and prevention of secondary injuries.

Monitoring & vital signs

This educational intervention resulted in increased awareness among EC nurses of the importance of assessing vital signs and was successful in increasing the number of patients with TBI who were monitored and had vitals reassessed. Frequent monitoring of vital signs can lead to earlier recognition and treatment of secondary injury, which is essential in the care of patients with TBI. This can be challenging in resource-limited settings and has been noted to be an issue in other African countries as well [26–28].

While monitoring did increase in the post-intervention group, it did not reach our target of 2-hourly reassessments over the first 24–48 h of hospitalization. On average, patients had 2.85 documented assessments at intervals of 4.5 h between vital signs over 16.76 h. This was an improvement from the pre-intervention group where the majority of patients had no reassessment of vital signs, however this cannot be considered intensive monitoring and is likely insufficient to achieve meaningful reductions in secondary injuries or mortality.

Assessment of all individual parameters improved significantly in the post-intervention group. Hypoxia was the most common insult in both groups. Studies in Tanzania, Rwanda and South Africa have also found that hypoxia is common and is a significant predictor of mortality in TBI [26,27,29]. 41.8% of patients who died from TBI in Tanzania experienced hypoxia and over half of a South African cohort had at least one documented episode of hypoxia or hypotension [26,27]. These secondary insults were less frequent in wards with more frequent monitoring protocols, again stressing the important role of monitoring in preventing secondary injuries [27]. In studies of TBI in HICs, rates of hypoxia ranged from 6 to 45% and appeared to decrease over time [10,30–32]. We were not able to quantify the duration of hypoxia or the number of hypoxic events, however the fact that over 50% of patients have at least one hypoxic episode may significantly impact survival. As noted previously, even one episode of hypoxia has been shown to substantially increase the odds of death in patients with TBI [9,12,13]. It is likely that improved access to ventilators could reduce the burden of hypoxic injuries and subsequent mortality. Other low-tech strategies to detect and manage hypoxic injuries also warrant investigation, especially in a population with such a high prevalence of hypoxia.

Secondary outcomes

While we expected that our intervention might lead to a decrease in time to CT, neurosurgical intervention or placement of an advanced airway, we failed to find a difference between groups. There are many factors outside the scope of this intervention including availability of operating theatres, financial constraints, functionality of the CT

scanner, lack of ventilators and availability of staff credentialed in advanced airway placement, that could also affect time to treatment.

Time to CT

In our regression model CT was found to have a protective effect on mortality. While this could be due to a survivor effect, it could also indicate that CT plays an important role in directing care. Prompt neuroimaging is critical in management of TBI as CT is needed to determine which patients are surgical candidates. In this study, with the exception of one patient, only patients who had a CT underwent neurosurgical intervention, suggesting that CT is a limiting factor in proceeding to definitive management. In both groups, median time to CT was long (9.48 h and 10.97 h) and all patients would likely benefit from more expedient imaging. While CT is available at Mulago, patients and their families must pay before these studies can be done. A CT of the brain costs UGX 150,000 (approximately USD50), which can be prohibitively expensive for many [20]. When a patient is unresponsive or has no family readily available, a waiver can be obtained from the hospital administration to proceed with CT without payment. This can be lengthy process and is not feasible at all times of day. In the post-intervention group, which had a higher proportion of severe TBI, 19 patients (7.4%) died before a CT scan could be done. In total, 23 patients died prior to CT and of these, only 3 died within the first 2 h after arrival. These patients may have had a greater chance of survival with timely CT to provide a diagnosis and guide management.

Time to neurosurgical intervention

Roughly 10% of patients in each group underwent neurosurgical intervention and the median time to surgery was 16–18 h from arrival. Prior studies have demonstrated similar delays in surgery at Mulago [8]. Most guidelines recommend surgical drainage of intracranial hemorrhage as soon as possible [35]. These recommendations are based on studies showing improved survival with early intervention [9,36–40]. Several recent studies of patients with TBI in Uganda and elsewhere in Africa demonstrated a similar relationship with mortality rising from 7.8% in patients who received timely surgery to 62% in those who did not [8,27,41]. As there were only a few patients in our study who actually had surgery, we were unable to assess any association between time to surgical intervention and mortality.

Time to advanced airway

Advanced airway placement occurred in only a small number of patients and was often significantly delayed. Regression analysis yielded an OR for mortality of 4.98 with advanced airway placement. This association could indicate that only severely injured patients are receiving advanced airways, or that by the time an airway is established the patient has already incurred secondary injuries that portend a poor prognosis. In this setting airway management is fraught with difficulty. Qualified providers are not always accessible and even when there is a clear indication for an advanced airway the limited availability of ventilators may preclude intubation. Patients who are intubated in the EC benefit from airway protection but may still incur hypoxic injuries as patients must either be bagged, or if breathing spontaneously receives supplemental O₂ via facemask or be left on room air since ventilators are only available in the ICU.

Limitations

There are several limitations to this study. Recruitment changed mid-way through the study due to logistical issues. Patients before the intervention were captured through screening charts at patient intake, while the post-intervention group was dependent on nursing initiative to enrol patients. This may have resulted in preferential enrolment of

patients with severe TBI. We tried to ensure that all nurses had completed the training session at least once, however, nursing reassignment is common in Uganda. The high turnover of nurses within the department makes it possible that at some points in the study not all nurses were trained. In addition, during the post-intervention period, another study on patients with TBI was also being conducted in the EC, which competed for the nurses' time and attention.

During the second phase of the study, MNRH began renovations and in the process all units were moved to the old hospital facilities. As a result of the renovations, the CT scanner was unavailable from May to July 2016 and patients had to be sent to neighbouring facilities for a CT. The trauma unit, HDU and ICU were also unavailable for several weeks during this time and there were no surgical capabilities for several days.

Many patients had delayed presentations to care, which could limit the impact of the intervention, however we felt it was important to include patients within two days of injury, as this is most representative of the population that is seen at MNRH [8]. Data collection was limited to what was documented on the study form or in the patient's chart and was often incomplete or lacking in detail. Several forms were not collected from patient's charts during their hospital stay and were not able to be located after discharge. This was a single-centre study, limiting generalizability. Additionally, renovations at the hospital resulted in limited availability of ICU and HDU beds as well as access to CT and may have mitigated any positive effects of our intervention.

Conclusion

While it was established that a structured nursing education program focused on limiting secondary injury improved monitoring of patients with TBI in Uganda, we were not able to demonstrate an effect on mortality. Monitoring of patients with TBI is a feasible and essential part of care in these settings but additional improvements across the entire care continuum are needed for adequate treatment of secondary injuries. The high mortality of these patients underscores the need for treatment strategies that can be effectively implemented in low resource settings. Potential approaches based on our study include implementation of low-cost pulse oximetry monitoring and cohorting of patients with TBI within the EC for more intensive monitoring. Access to oxygen, ventilators, IV fluids, cooling mechanisms, etc. should be ensured to allow for timely treatment of secondary injuries. Processes should be streamlined to expedite imaging and surgical intervention in critically injured patients. Improving the quality of care in the EC must be prioritized as most deaths occurred early before patients were transferred to other wards. Broader approaches include elaboration of trauma systems with an emphasis on early aggressive care and primary prevention such as helmet use and other road traffic safety interventions.

Dissemination of findings

Findings were disseminated via email to the various heads of the relevant departments that contributed to the data collection.

Authors' contribution

Authors contributed as follows to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: MG contributed 67%; HM 15%; TSL 8%; JM and JN contributed 5% each. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

Declaration of competing interest

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Medicine, Global Health Division. The authors declare no further conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.afjem.2020.05.013>.

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