

Challenges and Solutions for Traumatic Brain Injury Management in a Resource-Limited Environment: Example of a Public Referral Hospital in Rwanda

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Abstract

Objectives: We evaluated treatment strategies for traumatic brain injury (TBI) management in both a high-income country (HIC) (University of Virginia Health System) and a low-income country setting (Kigali University Teaching Hospital).

Methods: A review of the literature was performed to identify current strategies of TBI management in low and middle-income country (LMIC) settings. Additionally, personal communications with the neurosurgery and trauma teams at the University of Virginia (UVA) Medical Center and the Kigali University Teaching Hospital (KUTH) in Rwanda were employed.

Results: At UVA, there are specific TBI treatment guidelines in place; however, these guidelines are somewhat resource intensive and might not be appropriate in a resource-limited setting. There are unpublished national neurosurgical guidelines that include sections on TBI management, but most physicians informally surveyed were unaware of the existence of these guidelines. Notably, a contextually relevant, institution-specific TBI guideline is in the process of being developed at KUTH.

Conclusion: In an LMIC, such as Rwanda, interventions aimed at reducing the incidence of TBI, as well as predictive models to help allocate treatment resources, will likely help to improve outcomes in the short-term. Long-term improvement to provide outcomes similar to those seen in HIC will rely on increasing the supply of scarce resources, including trained neurosurgeons.

Categories: Emergency Medicine, Neurosurgery

Keywords: tbi, traumatic brain injury, rwanda, developing countries

Introduction

Traumatic brain injury (TBI) is defined as "an acute brain injury resulting from mechanical

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energy to the head from external forces" [1]. TBI is a major healthcare concern, which does not show regional predilection, but is universally found to be more common in adolescent to young males than other epidemiologic groups [2]. It is a major cause of disability and mortality in those younger than 40 years of age [2]. The incidence of neurotrauma is not well agreed upon with estimates ranging from 67-317 per 100,000 worldwide. Mortality rates from TBI range from 1% for minor head injury to 48% for severe head injury [2]. The incidence of TBI in the United States (US) has been quoted as 200 per 100,000 population from the National Head and Spinal Cord Survey, resulting in an estimated \$50 billion 1990 US dollars in direct and indirect costs [2]. There is a lack of consensus on the incidence of TBI in low and middle-income countries (LMIC) [1], but one study found the hospitalization rate of neurotrauma as 316 per 100,000 in South Africa, making it an area of highest incidence worldwide [2].

TBI disproportionately affects LMIC [3]. A meta-analysis comparing the US, other developed countries, and developing countries found that mortality rates declined between 1975 and 2009 in all groups, but that the rate of decline was lowest in developing countries [3]. Additionally, these countries started with the highest mortality rate, resulting in a statistically significant increase in mortality between developing countries and the US in 2009 [3]. There was no significant difference between the US and other developed countries [3].

Data targeting the epidemiology of TBI is sparse, with no concrete data available for Africa [1]. Most African literature discusses head injury instead of the more precise TBI, making direct comparisons difficult [4]. It is believed that there are two distinct peaks for TBI in Africa: children younger than 10 years of age and adolescent to young adults [4]. With increased age, the male:female ratio shifts from 1.4-1.7:1 in those younger than 10 years of age to 5.69:1 for all ages [4]. In young children in Africa, falls are the leading cause of injury, but this shifts to violence in the adolescent to young adult period; in both groups, motor vehicle accidents (MVA) are a close second [4].

Epidemiologic data from LMIC in general is difficult to obtain for TBI due to challenges regarding archival inadequacy, hospital overcrowding, and limited research funding [5]. After attempting to control for these factors in Johannesburg, Nell and Brown found that there was a 316 per 100,000 overall incidence of TBI, with a marked increase in TBI incidence between the African and white populations [6]. They found an incidence of 80 per 100,000 of fatal TBI [6]. They also found that etiologies of TBI differed by race, with interpersonal violence accounting for the largest percent of nonfatal TBI among Africans at 51%, while MVA accounted for the largest percent of nonfatal TBI among whites at 63% [6].

Even in high-income countries (HIC), it is difficult to study the epidemiology of TBI because 25-40% of TBI is not managed at a hospital in these countries [1]. However, several risk factors have been identified. Alcohol, male gender, ethnic minority, and low socioeconomic status are associated with increased risk of TBI [1-2]. Ethnic minority status also increases post-TBI mortality [1]. The highest incidence of TBI is seen in adolescents and young adults between 15 and 24 years of age, with transport-related TBI (i.e. motor vehicle accidents) being most common [1]. In terms of severity, 70-90% of all TBI is mild, with age not being a predictive factor [1]. However, of the 10-30% of all TBI that is classified as moderate or severe, 30-35% expires in the hospital within the first 30 days [1], making it a significant cause of morbidity and mortality.

TBI guidelines have been shown to improve outcomes in HIC. One study showed that the implementation of guidelines lead to 9.13 times higher odds ratio of good outcomes relative to poor outcomes [7]. Development and implementation of contextually adapted guidelines in resource-limited setting should also result in better outcomes in LMIC. Other studies of TBI management in LMIC have suggested improvements to algorithms used in both HIC and LMIC

settings [8]. In this study, we compare treatment algorithms between a center in a HIC (University of Virginia) and one in a LMIC (Kigali University Teaching Hospital) in order to evaluate differences in management and suggest improvements in TBI management in both HIC and LMIC practice settings.

Materials And Methods

A review of the literature was conducted to identify current TBI management strategies in LMIC. An Ovid Medline search was conducted utilizing the 'brain injuries' and 'developing countries' medical subject headings (MeSH) terms. These MeSH terms were then combined with the AND operator and further limited to English language articles involving humans. This resulted in 19 articles at the time of search on March 12, 2014. The retrieved articles were then individually reviewed for relevance to the current study. Criteria for relevance included articles relating to TBI management in Africa, or generalized to all LMIC. Notably, a search combining the 'brain injuries' and 'Rwanda' MeSH terms returned 0 results.

In order to determine the current treatment guidelines and protocols utilized at the University of Virginia (UVA) and the Kigali University Teaching Hospital (KUTH) in Rwanda, personal correspondence with neurosurgeons at each institution was employed.

Results

TBI management in HIC – example of University of Virginia Medical Center

At our institution, UVA, we have protocols in place for both mild TBI and moderate to severe TBI. If the patient sustained a mild TBI without loss of consciousness (LOC) or neurological symptoms, he or she can be managed conservatively [9]. If the patient did suffer from those symptoms, he or she is seen in consultation with physical medicine and rehabilitation, speech therapy, and occupational therapy and is followed as an outpatient according to the recommendations of the consultants [9].

For moderate to severe TBI, defined as a Glasgow coma score (GCS) < 9, there are several treatment goals [9]. These include international normalized ratio (INR) ≤ 1.4 , intracranial pressure (ICP) < 20 mmHg, cerebral perfusion pressure (CPP) between 60 and 70 mmHg, central venous pressure (CVP) between 8 and 12 mmHg, systolic blood pressure > 90 mmHg, platelets between 75,000 and 100,000, pCO₂ between 35 and 40 mmHg, SaO₂ > 92%, and serum Na between 150-165 [9]. We also have a goal of ICP monitor placement within two hours, and we empirically raise the head of the bed to 30 degrees, even without the ICP monitor in place [9]. If the ICP is greater than 20 mmHg, we first try sedation and analgesia with midazolam and fentanyl if an ICP monitor is in place and propofol and fentanyl if there is not an ICP monitor in place [9]. If that fails to adequately control ICP, mannitol at 0.25 - 0.5 g/kg bolus is tried [9]. If the ICP continues to remain elevated, a repeat computed tomography (CT) scan looking for other pathologies and a ventriculostomy are attempted [9]. If the ICP remains greater than 20 mmHg despite these interventions and an operative solution is indicated, the trauma surgery attending and neurosurgery resident on call pursue a decompression or other operative intervention [9]. These guidelines are summarized in Figure 1. Additionally, if the patient is taking aspirin or Plavix, the platelet function is at least partially restored with one to two units pooled platelets. If the patient is taking warfarin, the coagulaopathy is reversed with two units thawed fresh frozen plasma (FFP) [9]. If FFP fails to reduce the INR to ≤ 1.4 , prothrombin complex concentrate, factor VIIa, or additional FFP at 10cc/kg are utilized until the INR is normalized [9].

[9]"> [9]" itemprop="image"

FIGURE 1: TBI protocol at UVA[9]

Abbreviations – GCS: Glasgow coma scale, PM&R: physical medicine and rehabilitation, OT: occupational therapy, INR: international normalized ratio, CPP: cerebral perfusion pressure, CVP: central venous pressure, SBP: systolic blood pressure, PLT: platelet count, ICP: intracranial pressure

TBI management in LMIC – example of Kigali University Teaching Hospital

Based on clinical guidelines used at KUTH, all patients with head trauma should receive a random blood glucose, complete blood count, coagulation studies, blood typing and crossmatching, standard blood chemistries, toxicology screening, arterial blood gasses, and CT of the head [10]. Those patients who present with a GCS score of 14, or a GCS score of 15, and LOC lasting less than five minutes are treated with empiric elevation of the head of the bed, serial neurological exams every one to two hours, nothing by mouth until the patient becomes alert, and isotonic crystalloid infusions [10].

Patients who present with a GCS of nine to 12, or a GCS of 13 with CT abnormalities, or patients who suffered a LOC greater than five minutes, admission to the Intensive Care Unit (ICU) for monitoring is the first course of action [10]. Patients with normal head CT scans are monitored for improvement for 12 hours. If they have not improved within that time, repeat imaging is obtained [10].

Patients with a GCS of three to eight are admitted to the ICU and evaluated for signs of intracranial hypertension, such as pupillary dilation, asymmetric pupillary response to light, decerebrate or decorticate posturing, or progressive deterioration on serial neurologic exams [10]. If signs of intracranial hypertension are observed, the patients are intubated and hyperventilated, with a goal pCO₂ between 30-35 mmHg, as well as being paralyzed and sedated [10]. Mannitol diuresis is also performed when the mean arterial pressure is 70 mmHg or greater [10].

It is notable that these guidelines are for head injury and not specifically for TBI. Utilizing the classification of head injury instead of the more precise TBI seems to be common in the African literature [4].

A convenient sample of about half of the general practitioners working in the KUTH Emergency Department were informally surveyed and asked if they were aware of any guidelines in Rwanda to help direct the management of TBI patients; none of the doctors were aware of these guidelines (personal communication). KUTH has only five ICU beds and ventilators available, and the physicians usually lack the ability to perform arterial blood gas and check pCO₂ due to limited reagents in the lab. These limitations call to question the rate of compliance with these guidelines at KUTH, though there is no data currently available.

Further communication with physicians in Rwanda also shows that while the hospital has access to a CT scanner, scans cannot always be obtained in a timely manner. Additionally, there is still need for a neurosurgical operating microscope, an operating table with a Mayfield head holder, and a high-speed drill set for quickly cutting through the skull. There are also frequent shortages of Surgicel, shunt materials, cranioplasty materials, and external ventricular drainage systems. The ICU should also obtain improved capability for

nutritional management of TBI patients.

Discussion

TBI management in LMIC

There is a documented shortage of papers in the international literature addressing the management of TBI outside of developed countries [11]. Those few papers that are published investigate the epidemiology of TBI, but management and follow-up are not standardized enough to allow for meaningful comparisons between regions [11]. Africa is a neurosurgically-underserved area with an estimated one neurosurgeon per 6.36 million population in Africa [12]. The country of Rwanda does better and has a ratio of one neurosurgeon to about 5.7 million population, and there are currently programs attempting to improve this ratio further [12-15]. There are currently two trained neurosurgeons and two general practitioners who assist the service at KUTH. However, in the US, there is one neurosurgeon for every 65,580 population as of a 2013 study [16]. Intracranial pressure (ICP) monitors are not routinely used in Rwanda, and instead clinical clues must be used to infer the presence of increased ICP. The only MRI in the country was acquired in 2010 and is operated by the Rwanda Neurosurgery Centre in King Faisal Hospital in Kigali [17]. Hitimana, et al. set out to better characterize the burden of TBI at the Butare Teaching Hospital in Rwanda in 2009. In a series of 152 neurosurgical patients treated over a period of eight months in 2009, they found that 73% were admitted secondary to trauma [12]. Of those trauma patients, more than half suffered from TBI and accounted for 49.3% of all neurosurgical admissions [12]. However, only 12% of these patients received a CT scan, and only 10% of patients classified as mild TBI received a CT scan [12]. Notably, the authors also mentioned that the surgeons struggled with limited resource utilization facing shortages of both ICP monitors and mannitol [12]. The establishment of the Rwanda Neurosurgery Centre is an exciting step towards consolidating the available equipment and acquiring new neurosurgical equipment [15]. Knowledge of the TBI burden and centralized management of resources could help increase access to these resources and improve outcomes.

The KUTH Emergency Department recently concluded enrollment of a cohort of TBI patients that arrived for care over the preceding six months. This study aimed to understand the epidemiology and current outcomes of these TBI patients through direct observation of patients for their first four hours of care in the emergency department and daily follow-up until their discharge or death. The investigators hope that this new knowledge will help drive local quality improvement efforts while contributing more generalizable information about the impact of certain interventions and timeliness of care on patient outcomes in resource-limited settings (personal communication).

TBI management in HIC vs LMIC

In the US, 40-60% of patients with neurotrauma are not sufficiently treated, and similar treatment rates are also observed in the UK [2]. However, outcomes are hard to measure because neuropsychological testing is not standardized between centers [2], making it difficult to quantify the outcomes of best medical management. These perceived discrepancies in care lead to the development of guidelines for TBI management. The most current guidelines from the Brain Trauma Foundation are summarized in Table 1. Notably, the majority of these guidelines are based on low level (Level II or III) evidence [18].

Treatment guidelines, coupled with the use of ICP monitors, have been essential in increasing functional rates after neurotrauma [7, 19]. However, while current guidelines are effective in the developed world, they have been less effective in the developing world, possibly due to lack of infrastructure, ICU availability, and emergency medical services [20]. De Silva, et al. found that mortality was increased in LMIC compared to HIC following severe TBI. However, LMIC were

shown to have decreased rates of disability compared to higher income countries following mild and moderate TBI, likely due to psychosocial differences in the definition of disability between regions rather than an actual difference in post-treatment functional status [21]. Most comparative studies between HIC and LMIC use dichotomous outcomes (i.e. death from TBI versus survival after TBI), which does not allow for more in-depth analysis of the challenges between these two practice settings [20]. One study attempting to overcome this limitation compared a US treatment center to two different treatment centers in Jamaica and found that there was a significant increase in utilization of head CT, ICP monitoring, ICU admission, and neurosurgical intervention in the US versus Jamaica, with a significantly longer length of stay in the US. However, interestingly, there was not a significant difference in length of ICU stay between those patients who were admitted to the ICU [20]. Also, those patients treated in the US had a significantly lower mean Glasgow outcome score (GOS). However, the difference was less than one point, and the implications of a fractional difference in GOS score are unclear [20]. They found the overall mortality to be similar in all three locations [20], indicating that outcomes need not be inferior in LMIC.

Topic	Recommendation
BP Control	Avoid systolic BP > 90 mmHg
ICP management	Use mannitol diuresis to lower ICP in those patients with clinical signs of increased ICP, or who have invasive ICP monitors in place
Hypothermia	There are no clear data for or against prophylactic hypothermia
ICP monitors	ICP monitors should be used in all salvageable patients with severe TBI and abnormal CT
ICP goals	Treat for ICP < 20 mmHg
Volume resuscitation	Avoid aggressive attempts to maintain cerebral perfusion because of the risks of ARDS
Medical ICP control	Barbiturates to control elevated ICP is indicated in those refractory to other treatments, but not for prophylactic administration to induce burst suppression Propofol may also be used
Caloric replacement	Patients should be fed to attain full caloric replacement by post-injury day seven
Anticonvulsants	Prophylactic anticonvulsants to prevent late post-traumatic seizures is not indicated, but they may be used to control early post-traumatic seizures
Hyperventilation	Prophylactic hyperventilation is not recommended
Steroids	Steroids are not recommended for ICP control

TABLE 1: Summary of Brain Trauma Foundation TBI Guidelines[18]

Abbreviations – BP: blood pressure; ICP: intracranial pressure; TBI: traumatic brain injury; ARDS: acute respiratory distress syndrome; CT: computed tomography

Recommendations for LMIC

Limited resources are a major challenge in LMICs, such as Rwanda. Protocols, such as those

used at our institution, are not feasible when CT scanners and ICP monitors are not readily available. While CT scanners are available at KUTH, the lack of ICP monitors means that physicians may not be able to detect changes in ICP as easily and have to rely on clinical clues instead of measured data to determine if a patient has increased ICP.

Allocation of limited resources is a major problem faced in LMIC [22]. In an effort to centralize resources, the Rwanda Neurosurgery Centre was recently founded. However, implementing TBI protocols to help guide management and resource allocation will likely help to improve outcomes. The Emergency Department and Neurosurgery Division at KUTH are collaboratively designing a context specific clinical practice guideline for the initial assessment and management of TBI patients in the Emergency Department. Following its implementation, they will assess the impact of this guideline by comparing patient outcomes to those from a cohort of TBI patients treated before implementation of these guidelines (personal communication).

In resource-limited areas, predictive models to dictate need for CT and other interventions are imperative [22]. Subaiya, et al. proposed a model utilizing GCS score, age, pupil reactivity, extracranial injury, and time elapsed since injury to provide risk stratification decision-making in LMIC [22]. Their model offers good predictive utility with a c statistic of 0.71 (the c statistic is a measure of the ability of a model to discriminate between outcomes, with a value of one being perfectly discriminating, and a value of 0.5 being random) [22]. Additionally, the establishment of a neurotrauma care center would help ensure that physicians have access to the resources they require. Rubiano, et al. suggest that a neurotrauma care center should have at a minimum a CT scanner available 24 hours a day, a neurosurgeon available 24 hours a day with a time to arrival of less than 15 minutes, immediate availability of operating rooms, immediate availability of an ICU bed and ICU physician, and availability of other specialists for advanced trauma care [23]. However, in LMIC where this may not be feasible, they suggest that resources be allocated by demonstrated need, to which a first necessary step is the construction of a database and a validated predictive model of cases so hospital administrators can rationally allocate resources [23]. Additionally, early intervention by paramedics should be improved. Early trauma care by paramedics skilled in resuscitation and timely evacuation to a hospital setting has been implicated in a 15-30% reduction in deaths in various parts of the world [19]. Because TBI tends to result secondary to MVA, an interdisciplinary and systems based approach to prevention with inputs from police, road transport, health, education, and the media could also help decrease the incidence of TBI [19], resulting in decreased disease burden and increasing the availability of resources when TBI does occur. Functionally focused rehabilitation programs, which are far more common in HIC, have also been shown to improve outcomes after TBI and could be implemented in LMIC [24].

While these are short-term solutions, the long-term goal should be to increase the availability of scarce resources, which seems to be the major hurdle in LMIC. To that end, training for additional neurosurgeons in order to decrease the ratio of population to neurosurgeons should be instituted. There have already been steps toward increasing the supply of neurosurgeons in Rwanda with the founding of a neurosurgery residency program in Rwanda as of 2011 [25]. Along with the increase in number of neurosurgeons, increases in medical capabilities, including an increased capability to perform ICP monitoring, would help alleviate the healthcare disparities and hopefully bring the outcomes from TBI in LMIC more in line with those seen in HIC. The final long-term goal should be the capability for compliance with TBI management guidelines, which are currently in place in HIC to allow for similar outcomes between LMIC and HIC.

This study investigated the differences in management of TBI between HIC and LMIC by using the UVA Medical Center as an example of management of TBI in a HIC, and the KUTH in

Rwanda as an example of TBI management in a LMIC. While this study is able to find differences in management, it is not able to find a causal connection between differences in management and the poorer outcomes seen in LMIC. Further studies implementing changes in TBI management in a LMIC setting and tracking subsequent outcomes from these changes are needed in order to prove that changed management will be effective in the LMIC setting.

Conclusions

TBI is a major concern in LMICs, such as Rwanda [2]. Differences exist between the outcomes that are achieved in HIC and LMIC [21]. These differences in outcomes are likely due to limited resources in LMIC. In this setting, applying the guidelines that appear to benefit HIC will likely not be helpful, since the interventions are resource intensive. The use of predictive models to ration resources, coupled with early paramedic trauma care and rehabilitation programs focused on functional endpoints will be crucial to improve outcomes in resource-limited settings. Preventative programs aimed at reducing the incidence of TBI will also help to reduce disease burden. In the long-run, increasing the supply of limited resources, including attracting and employing more neurosurgeons, will likely help improve outcomes and close the disparity between LMIC and HIC.

Additional Information

Disclosures

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First and second authors contributed equally.

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