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ECONOMIC ANALYSIS OF SEVERE TBI TREATMENT IN UGANDA

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ABSTRACT

Although the majority of the global burden of disease occurs in low- and middle-income countries, there is a paucity of data surveillance and analysis on the incidence of, morbidity and mortality associated with, and economic costs attributable to traumatic brain injury (TBI).A prognostic model was used to estimate outcomes of conservative and neurosurgical treatment for severe TBI based on data from a cohort of patients at the national referral hospital, Mulago Hospital, in Uganda during a 13-month study period. To evaluate the long-term impact of treatment for severe TBI, averted DALYs were calculated and converted to dollars using the human capital and the value of a statistical life (VSL) approaches. This cohort was then used as a representative sample for assessing the benefit of treating severe TBI for all of Uganda. During the study period, 127 cases of severe TBI were treated averting 1,448 DALYs [0,0,0], 1,075 DALYs [3,1,0.04], or 974 DALYs [3,1,0.03]. Using the human capital approach, the economic benefit of intervention ranged from $1.3 million to $1.7 million. The VSL approach estimated an economic benefit of $282,902 to over $11 million. The health benefit of treating severe TBI for all Ugandans was estimated at between about 11,000 and 17,000 averted DALYs per year with an annual potential economic benefit of $15 to $20 million as determined with the human capital approach and $3.3 to $130 million with the VSL approach. Treatment of severe TBI in Uganda has the potential to reduce a significant proportion of morbidity, mortality, and economic burden, which indicates the importance of treating severe TBI in developing countries.

Keywords: Economic analysis, severe TBI, disease burden, global surgery, low- and middle-income countries.

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INTRODUÇÃO

Traumatic brain injury (TBI) is one of the leading causes of morbidity and mortality, resulting in death or hospitalization of at least 10 million people every year (1,2). Globally, TBI contributes to an estimated 425 years of healthy life lost due to disability (YLDs) per 100,000 annually, making it the foremost cause of death and disability in people under the age of 40 years old (1). As of 1996, approximately 57 million people worldwide were living with TBI serious enough to require at least one hospitalization (2-4). The largest burden of disease attributable to TBI is in low- and middle- income countries (LMICs), particularly those within sub-Saharan Africa. Increasing trends in incidence of TBI in these countries are due to greater population density and higher rates of injury (2-4). Limited health care access and resources further exacerbate TBI death and disability. An estimated 15% of incident skull fracture injury patients receive treatment in sub-Saharan Africa compared to 90% in high-income countries (1). LMICs are also known to experience worse outcomes and higher mortality rates associated with severe TBI, defined by a Glasgow Coma Scale (GCS) score from 3 to 8, than those experienced by high- and middle-income countries (5-6). Given its predilection for young adults and projected increase in incidence within the next decade, TBI death and disability will continue to affect the most productive sector of the sub-Saharan African workforce (3).

Appropriate hospital intervention, including prompt critical care and neurosurgical treatment to minimize secondary brain injury, plays a crucial role in decreasing the morbidity and mortality attributable to severe TBI (7-8). Expanding access to critical care and neurosurgical treatment through investment in training and technology not only improves community health status, increases the number and quality of health care professionals, and contributes to overall health care capacity development and systems strengthening (9), but also has potential to reduce the significant economic burden posed by TBI in low and middle income countries (LMICs). Unfortunately, standardization of treatment across a wide variety of settings is complicated by severe resource limitations within many of the countries that are disproportionately affected (6). This reality necessitates evidence-based decision making in resource allocation, prioritization and health care sector planning. Cost-effectiveness analysis is a mechanism used by policymakers in many countries and the World Health

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Organization for determining whether the initiation or continuation of a medical or surgical intervention is providing benefit that is reasonably proportional to cost (10-11). Although interventions focusing on infectious diseases (e.g. immunizations) have been traditionally emphasized throughout the global health community for their low benefit to cost ratios, recent evidence suggests that surgical treatment and emergency care for potentially disabling traumatic injuries are comparably cost-effective (12-14).

While the economic burden on TBI in the United States has been extensively studied (15), we are not aware of any studies assessing the potential economic impact of treatment for TBI in a sub-Saharan African (SSA) or other LMIC. For this study, we used a cohort of patients with severe TBI at the primary national hospital in Uganda as a case study to evaluate the benefit in terms of disability-adjusted life years (DALYs) averted and the broader economic impact of severe TBI treatment, including neurosurgical and critical care. Economic evaluations are important inquiries that help to better frame a country's economic investment in health. Currently, Uganda spends 9.8% of its $23.61 Billion USD GDP on health, with only a small fraction of health spending designated for surgery (24)

METHODS

SETTING AND SUBJECTS

Mulago Hospital is a 1,500-bed national referral hospital located in Kampala, which is the largest city and capital city of Uganda. It serves the approximately 1.6 million residents of Kampala and 1.5 million people living in neighboring districts and beyond (16). Since 2007, the hospital has benefited from a twinning program with Duke University Medical Center and Duke Global Health Institute named the Duke Global Health PLUS (Placement of Life-changing and Usable Surplus) Program. The Duke Global Health PLUS Program provided contextually appropriate anesthesia machines, hemodynamic monitoring equipment, and surgical equipment for the five elective operating rooms, a recovery room, and an intensive care unit (ICU) at Mulago Hospital. Additionally, the program began training camps run by Duke neurosurgeons, anesthesiology personnel, surgical operating room nurses and technicians, ICU specialists, recovery and floor nurses and clinical engineers. Annual training camps and continuing medical education (CME) courses are held for four of Uganda's five neurosurgeons, in addition to Ugandan anesthesiology personnel, nurses, and clinical engineers.

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A 13-month period from May 2008 to June 2009 was selected as a representative sample of patients with severe TBI (n=127) who were treated by the Mulago Hospital faculty and staff with support from the Duke Global Health PLUS Program. We performed secondary analysis of data collected through retrospective clinical surveillance on all patients who received conservative and surgical treatment for severe TBI (GCS of 3 to 8) at Mulago Hospital during this study period. The following variables were included in the data set: age, gender, mechanism of injury, computed tomography (CT) result, lowest and highest GCS with dates, presenting blood pressure, signs/symptoms (i.e. vomiting, pupil fixation, pupil symmetry), surgical procedure, ancillary treatment, incident date, admission date, operation date, discharge date, and discharge status. The Ugandan health care providers were trained to treat severe TBI according to the Brain Trauma Foundation guidelines. Therefore we assumed that all patients were treated in adherence to these guidelines to the extent possible given limitations associated with the resource setting (17). We scored each patient using the core International Mission for Prognosis and Analysis of Clinical Trials in TBI (IMPACT) model, which is an international, externally validated prognostic model that provides the probability of outcomes at 6 months following treatment by GOS category (i.e. mortality represented by GOS 1, unfavorable outcome represented by GOS 2-3, and favorable outcome represented by GOS 4-5) (18).

Quantification of Averted DALYs

The DALY is a health parameter that measures premature mortality and morbidity associated with an illness or disease, where one DALY represents one year of healthy life lost. DALYs are calculated by adding years lost due to disability (YLD) to years of life lost (YLL) using the following basic formulas: DALYs = YLD + YLL, where YLD = I x D x DW, YLL = N x LD, I = incident cases, D = duration of illness, DW = disability weight (i.e. expert-derived determinations of social preferences and valuations of health ranging from 0 to 1, where 0 represents complete health and 1 represents death), N = number of deaths and LD is life expectancy at age of death. For the purpose of sensitivity analysis, DALY calculations are frequently modified to take into account discounting (i.e. factoring in preference for health in the present relative to health in the future) and age-weighting (i.e. factoring in relative value for a year of health life depending on age). By calculating the

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difference between DALYs in a cohort of treated individuals and DALYs in a cohort of counterfactual untreated individuals, averted DALYs are calculated as a measure of the premature death and disability averted by treatment (19).

We calculated the number of averted DALYs attributable to treatment for incident severe TBI at Mulago Hospital during the study period. We assumed that untreated patients would die without treatment and have no years of life lost due to disability (i.e. YLD=0 and DALYs = YLL); and we assumed that treated patients would have an average-weighted outcome based on GOS category probabilities predicted using the IMPACT core model (18). Disability weights were determined for each GOS category using World Health Organization (WHO) definitions of disability weighting (20). The disability weight for GOS-1, that is death, is 1; GOS-2 and GOS-3, characterized by vegetative state and severe disability respectively, have a combined disability weight of 0.828; and the most favorable outcome, GOS-4 and GOS-5, representing moderate disability and good recovery respectively, have a combined disability weight of 0.203. For simplification, outcome-associated disability weights were applied immediately at the time of the severe TBI diagnosis as opposed to 6 months following the severe TBI diagnosis as predicted by the IMPACT core model (18). Duration of illness was assumed to be the mean Ugandan life expectancy at the age of death (12). As recommended in the DALY literature, we calculated unweighted averted DALYs with no age-weighing or discounting (i.e. DALYs [0,0,0]); weighted averted DALYs with an age weighting factor that peaks at 25 years (β=0.04) and a 3% discount rate annualy (i.e. DALYs [3,1,0.04]); and weighted averted DALYs with an age weighting factor peaking at two-thirds of mean Ugandan life expectancy during the study period (β=0.03) and a 3% discount rate annualy (i.e. DALYs [3,1,0.03]) (22).

Quantification of Economic Benefit

The potential benefits attributable to treatment for severe TBI were translated into economic terms using two methodologically sound approaches. Economists advocate converting DALYs averted into dollars using the concepts of human capital by way of the Gross National Income (GNI) per capita and the value of a statistical life (VSL) (23). The human capital approach, calculated by multiplying the GNI per capita by DALYs averted, is considered a more conservative estimate of economic benefit, because it is based on the idea that

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an individual's societal value is determined by their potential contribution to the national economy and it does not factor in associated social benefits (e.g. decreased expense for family). We calculated an upper and lower limit of economic benefit with the human capital approach using the unweighted [0,0,0] and weighted [3,1,0.04] averted DALYs, respectively. The mean Uganda GNI per capita was calculated from the World Bank data (24).

The VSL approach represents a more generous estimate of economic benefit that reflects the amount of money a group of people is willing to pay to reduce premature mortality. As such, the VSL approach takes the value of welfare into consideration more so than the value of productivity produced by the human capital approach (23,25-26). Uganda, like many LMICs, does not report a VSL, thus country-specific VSL was estimated using of the VSL in the USA using the following formula: VSL(Uganda) = VSL(USA)*[GNI(Uganda)/GNI(USA)]IE-VSL, where VSL(USA) is $8.3 million (in 2012 USD) (27,28) GNIs(USA) is $46,380 (in 2012 USD) and GNI(Uganda) is $1,180 (in 2012 USD) (24), and IE-VSL is income elasticity of VSL (IE-VSL of 0.55 estimates the upper limit and IE-VSL of 1.5 estimates the lower limit of VSL) (23,29). We then calculated the economic benefit with the VSL approach using the following formula: Economic benefit = V*avertedDALYs(3,1,0.03), where V is the constant value of a statistical life year (25,29).

To estimate broader health and economic benefit, we calculated the average averted DALYs and economic gain per patient for each method by dividing the total averted DALYs and economic benefit by the number of patients in each group. Assuming the Mulago Hospital catchment area population of around 3 million people is a representative sample of the Ugandan population of around 34 million people, roughly 1,500 Ugandans could potentially benefit from treatment for severe TBI every year (16,30). Using this ratio and the average averted DALYs and economic gain per patient, potential health and economic benefit for all of Uganda was approximated.

RESULTS

CLINICAL DATA

One hundred twenty-seven patients received treatment for severe TBI at Mulago Hospital from May 2008 to June 2009. The mean age at treatment was 26 years, and 69% of the patients were under the age of 40 years (n=88). Road traffic accidents (68%) and assault (17%) accounted for the majority of cases. Of the 28 patients who

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underwent neurosurgery, 14 received craniotomies, 8 received craniectomies, and 6 received burr holes. The in-hospital surgical mortality rate was 53%. Sixteen surgical patients (57%) were discharged or died with improved GCS scores (i.e., greater than 8). The majority of patients were treated conservatively (n=99); 18% of conservatively treated patients died before discharge and 84% were discharged or died with improved GCS scores.

AVERTED DALYS AND ECONOMIC BENEFIT

One hundred twenty-seven cases of severe TBI were treated at Mulago Hospital averting 1,448 DALYs [0,0,0], 1,075 DALYs [3,1,0.04], or 974 DALYs [3,1,0.03] (Table 1). Using the human capital approach, the economic benefit of intervention ranged from approximately $1.3 million to $1.7 million. The VSL approach estimated an economic benefit of $282,902 to over $11 million (Table 2). Conservatively treated patients were estimated to receive more economic gain than patients treated with neurosurgical intervention (Table 3). For Uganda, this correlates to between about 11,000 and 17,000 averted DALYs per year and an annual potential economic benefit of $15 million to $20 million using the human capital approach and $3.3 million to $130 million using the VSL approach, without taking into account the cost of treatment.

DISCUSSION

To our knowledge, this study is the first to attempt quantification of the health and economic benefits of conservative and neurosurgical treatment for severe TBI in an LMIC or in SSA. Traumatic brain injury is a leading cause of loss of life and function in the developing world. Consistent with the findings in our study, the majority of TBI in countries worldwide is caused by road traffic injuries (31). LMICs have the highest disease burden of TBI due to massive growth in motor vehicle numbers, higher numbers of people injured per crash, poor enforcement of traffic safety regulations, inadequate public health infrastructure, and poor access to health services (1,3,32). Moreover, our study demonstrated TBI's predilection for males and young adults, who are the most productive sector of the developing world workforce. Given the growing incidence of TBI, and understanding of the health and economic burden associated with TBI is paramount (3)

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Table 1 - Total DALYs averted from severe TBI treatment at Mulago Hospital

Treatment	Cases	Total DALYs Averted		
		DALYs [3,1,0.04]	DALYs [0,0,0]	DALYs [3,1,0.03]
Conservative	99	952	1286	860
Neurosurgical	28	123	162	114
Total	127	1075	1448	974

Table 2 - Economic benefit of severe TBI at Mulago Hospital (in USD)

Methodology	Lower Limit	Upper Limit
Conservative		
Human Capital	$1,123,360	$1,517,480
VSL	$249,791	$9,818,041
Neurosurgical		
Human Capital	$145,140	$192,340
VSL	$33,112	$1,301,461
Total		
Human Capital	$1,268,500	$1,708,640
VSL	$282,902	$11,119,502

Table 3 - Economic gain per patient (in USD)

Methodology	Lower Limit	Upper Limit
Conservative		
Human Capital	$11,347.07	$15,328.08
VSL	$2,523.14	$99,172.13
Neurosurgical		
Human Capital	$5,183.57	$6,869.29
VSL	$1,182.57	$46,480.75
Total		
Human Capital	$9,988.19	$13,453.86
VSL	$2,227.57	$87,555.13

Data on the burden of disease attributable to TBI in SSA are based on expert-derived estimates due to lack of standardized TBI surveillance systems in most countries throughout the world. Increased data collection efforts are required in order to strengthen our understanding of the most pressing problems affecting LMICs. In the present study, we used the data from a cohort of patients at the national referral hospital of Uganda to evaluate the long-

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term impact of treatment for severe TBI during a 13-month study period. This cohort was used as a representative sample for assessing severe TBI-related health benefit using averted DALYs and economic benefit using the human capital and VSL approaches for all of Uganda. The VSL approach for converting averted DALYs into dollars is the more widely accepted methodology for approximating economic benefit due to its basis in human behavior (25,29). However, even the most conservative estimates reveal a health benefit of 974 averted DALYs [3,1,0.03] with a respective economic benefit of over $280,000 (VSL approach) for patients treated at Mulago Hospital and a health benefit of 11,00 averted DALYs [3,1,0.03] with a respective economic benefit of $3.3 million (VSL approach) for patients treated all throughout Uganda over the course of 13-months.

The present study is limited by its reliance on a set of assumptions. Long-term data was not available for any of the patients, which necessitated the use of a predictive model. While the IMPACT models have been externally validated and are widely used, other prognostic models have been shown to be more accurate for cohorts with TBI in LMICs (18,33,34). Though our data set contained an inadequate amount of detail to fill in all of the variables necessary to compute outcome probabilities using these other models, mortality data seems to support the IMPACT prognostic model (Figure 1). While the IMPACT prognostic model predicted an average of 44.6 people with GOS = 1 at six months after admission, 33 people died before discharge. We would also expect that some more people died between time of discharge and six months after admission. Another limitation is the lack of published literature investigating the effects of severe TBI on the life expectancy of Ugandans. While severe TBI has been shown to confer an increased risk of mortality in high-income countries, the practical effect that this may have on premature mortality given poorer general health and shorter life expectancies remains unclear (30,35). Also, many similar studies that assess the economic benefit associated with treatment include the treatment cost per averted DALY; however, inadequate cost data prevented us from doing so (25,29). The number of averted DALYs also has to be conservative, as many patients who sustained a severe TBI and who were dead at the scene of the accident would not go to the hospital but directly to the morgue, thus avoiding detection with our hospital-dependent data gathering. Finally, the limitations associated with using averted DALYs as an appropriate measure of avoidable morbidity and mortality have been well documented elsewhere (36,37).

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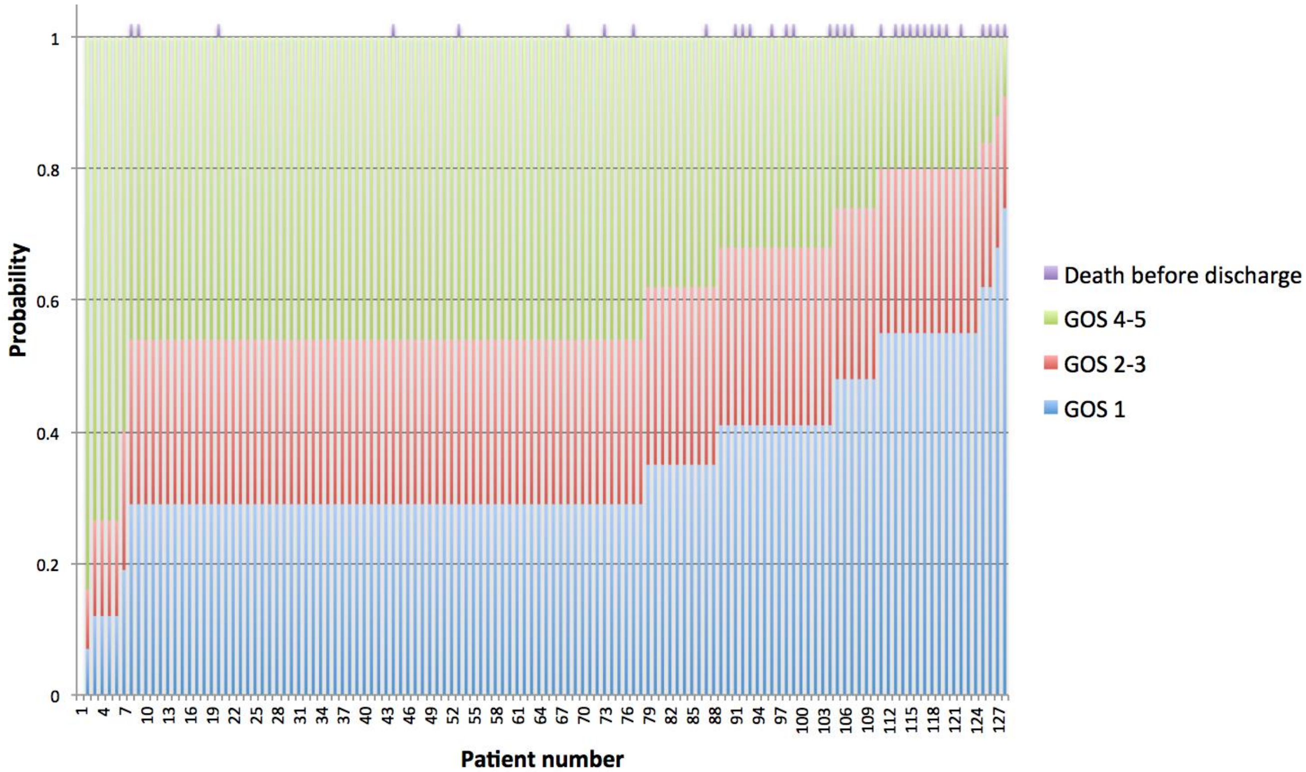

Figure 1 - Comparing IMPACT prognostic model probabilities with mortality before discharge

CONCLUSION

Our study suggests that the health and economic burden associated with severe TBI is extensive in Kampala and we conclude that nationwide treatment for severe TBI may provide economic benefit between $3.3 million and $130 million for Uganda. The amount of economic gain produced from treating a small cohort of patients indicates the importance of treatment for severe TBI in developing countries in sub-Saharan Africa. We hypothesize that other LMICs would similarly benefit significantly from decreasing the death and disability associated severe TBI. Programs focusing on increased training and technology transfers in order to contribute to health care capacity development and systems strengthening, as well as growth of initiatives focusing on prevention, are essential to reducing the global burden of TBI.

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