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The economic consequences of neurosurgical disease in low- and middle-income countries

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OBJECTIVE The objective of this study was to estimate the economic consequences of neurosurgical disease in low- and middle-income countries (LMICs).

METHODS The authors estimated gross domestic product (GDP) losses and the broader welfare losses attributable to 5 neurosurgical disease categories in LMICs using two distinct economic models. The value of lost output (VLO) model projects annual GDP losses due to neurosurgical disease during 2015–2030, and is based on the WHO's "Projecting the Economic Cost of Ill-health" tool. The value of lost economic welfare (VLW) model estimates total welfare losses, which is based on the value of a statistical life and includes nonmarket losses such as the inherent value placed on good health, resulting from neurosurgical disease in 2015 alone.

RESULTS The VLO model estimates the selected neurosurgical diseases will result in $4.4 trillion (2013 US dollars, purchasing power parity) in GDP losses during 2015–2030 in the 90 included LMICs. Economic losses are projected to disproportionately affect low- and lower-middle-income countries, risking up to a 0.6% and 0.54% loss of GDP, respectively, in 2030. The VLW model evaluated 127 LMICs, and estimates that these countries experienced $3 trillion (2013 US dollars, purchasing power parity) in economic welfare losses in 2015. Regardless of the model used, the majority of the losses can be attributed to stroke and traumatic brain injury.

CONCLUSIONS The economic impact of neurosurgical diseases in LMICs is significant. The magnitude of economic losses due to neurosurgical diseases in LMICs provides further motivation beyond already compelling humanitarian reasons for action.

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A SIGNIFICANT proportion of the global burden of disease requires surgical care,[38,44,48] yet 5 billion people globally lack access to safe, affordable, and timely surgical care.[6] Moreover, the scarcity of access to surgery is especially bleak with respect to neurosurgical conditions.[12,24] A burgeoning evidence base suggests that surgical interventions, including neurosurgery, can be cost-effective, challenging long-held dogma that deems subspecialty surgery too expensive for resource-poor settings.[19,45]

Poor access to surgical care not only negatively impacts health, but also has the potential to harm the economies of low- and middle-income countries (LMICs). While the exact relationship between health and wealth is the ongoing subject of debate,[3,16,29] microeconomic literature provides evidence for a strong association between improved health and increased income and productivity.[18,40] Additionally, a large body of macroeconomic literature has convincingly demonstrated a positive effect of health on aggregate economic growth.[9,11,13,15,17,18,26,30,31]

ABBREVIATIONS DALY = disability-adjusted life year; EPIC = Projecting the Economic Cost of Ill-health; GBD = Global Burden of Disease; GDP = gross domestic product; HIC = high-income country; IE = income elasticity; IHME = Institute for Health Metrics and Evaluation; LCoGS = Lancet Commission on Global Surgery; LMICs = low- and middle-income countries; PPP = purchasing power parity; TBI = traumatic brain injury; USD = US dollars; VLO = value of lost output; VLW = value of lost economic welfare; VSL = value of a statistical life; VSLY = value of a statistical life year.

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Recent efforts have also highlighted the economic consequences from individual surgical diseases,[5,8,45] as well as broader categories of disease.[2,7,14] To date, however, no study has established the economic consequences of neurosurgical diseases in LMICs at the global level.

This study aims to understand the economic burden of selected neurosurgical diseases in LMICs by adapting the same methodologies that were used for the Lancet Commission on Global Surgery (LCoGS), which estimated the economic consequences of 5 categories of surgical diseases.[7,33] We estimate gross domestic product (GDP) losses and the broader welfare losses attributable to 5 neurosurgical diseases in LMICs.

Methods

Definition and Scope of Neurosurgical Disease

We began by selecting 5 disease categories that regularly require the involvement of a neurosurgeon: traumatic brain injury (TBI), cancers of the brain and nervous system, neural tube defects, cerebrovascular accident, and infections of the CNS. While these disease groupings were chosen in part due to data limitations that precluded inclusion of some diseases, such as degenerative and traumatic spinal conditions, they were also believed to be representative of the majority of the neurosurgical disease burden, especially with respect to mortality.

Burden of disease estimates were obtained from the Institute for Health Metrics and Evaluation's (IHME) most recent Global Burden of Disease (GBD) Study (GBD2015),[42,43] with the exception of TBI. IHME provides disease burden estimates only for causes of injury (e.g., road traffic accidents), and not the nature of injury (e.g., TBI, spinal injury). Details of the methodology for estimating mortality rates for TBI and adjustments to IHME data are provided in the Appendix. To estimate future mortality rates, we attained mortality rates by disease, country, age group, and sex for the years 2005 and 2015, and calculated an annualized rate of change that was used to create mortality rate projections. We should note that while this study does not separately examine hydrocephalus, as it is not a discrete GBD2015 cause, the burden of hydrocephalus is accounted for as sequela in other GBD categories included in this analysis.

Given that the involvement of a neurosurgeon is not always required for all cases of the included disease categories, the burden estimates obtained from IHME were adjusted. To accomplish this, we relied on a survey that asked participants from high-, middle-, and low-income countries to estimate the proportion of patients for each disease that require consultation by a neurosurgeon.[23] The mean results from the survey were applied.

Overview of Approaches

Two economic approaches are used to estimate the macroeconomic consequences of the selected neurosurgical diseases. It is important to note that the models are complementary as they have distinct economic perspectives; consequently, the results should not be directly compared. The value of lost output (VLO) model projects annual GDP losses due to disease during 2015–2030, the same period evaluated by the LCoGS. The value of lost economic welfare (VLW) model estimates total welfare losses resulting from neurosurgical disease in 2015. The VLO and VLW models therefore differ with respect to the meaning of economic loss and the period during which losses are estimated. The counterfactual scenario in both approaches is absence of disease.

Value of Lost Output

The VLO approach relies on a model supplied by the WHO known as EPIC ("Projecting the Economic Cost of Ill-health"), which relates projections of disease-specific mortality rates and the consequent decrease in the labor supply over time to decreased economic output, or GDP.

The EPIC model relies on the Cobb-Douglas production function, which expresses economic output as a function of labor supply, capital, economic productivity, and country- and time-specific factors. By utilizing available projections on these metrics, it can simulate a counterfactual scenario in which one or more of these parameters are changed, in this case mortality-related changes of the labor supply. By utilizing age-, sex-, country-, and year-specific mortality and population estimates, we can account for the changes in size, composition, and average experience of the workforce.[21]

Value of Lost Welfare

The VLW model uses an economic concept termed the value of a statistical life (VSL), which incorporates nonmarket losses such as forgone leisure time and the value placed on good health in and of itself.[41] The VSL is a measure of the maximum amount an individual is willing to give up for mortality risk reductions. It can be derived empirically from wage differentials related to the mortality risks of different occupations, or using survey-based stated-preference methods. Formal VSL studies have been performed primarily in high-income countries, so these estimates need to be adjusted based on the income levels in different countries. The method for transferring VSL estimates from one country to another depends on the income elasticity (IE) of the VSL (IE-VSL). IE-VSLs of around 0.55 are commonly used when transferring estimates between high-income countries, but recent literature suggests a higher value may be more appropriate.[28,41] We have therefore used a more conservative IE-VSL of 1.0. Research suggests that the VSL varies with the age of the individual. Contrary to what intuition might suggest, it follows an inverted U-shape, and we account for this in our model.[4,36]

By treating the VSL as if it were the present value of an annuity, it can be translated into the value of a statistical life year (VSLY), which can, in turn, be used to value disability-adjusted life years (DALYs), a health metric that captures mortality and morbidity.[37] Because of the way DALYs calculate the burden of disease due to premature death,[35] the VLW approach takes a long-run view of mortality and includes the value of lost life in 2015 plus the present value of discounted future effects due to potential life lost. Morbidity effects are based on prevalence estimates, and therefore only include the effects of disease in

TABLE 1. Total value of GDP losses and percentage of potential cumulative GDP lost secondary to neurosurgical diseases (2015–2030)

Disease	Low Income	Lower-Middle Income	Upper-Middle Income
CNS cancer	$3 (0.02%)	$59 (0.02%)	$225 (0.03%)
CNS infection	$21 (0.10%)	$182 (0.05%)	$53 (0.01%)
Neural tube defects	$2 (0.011%)	$5 (0.001%)	$12 (0.002%)
Stroke	$49 (0.24%)	$883 (0.25%)	$1718 (0.23%)
TBI	$20 (0.10%)	$313 (0.09%)	$842 (0.11%)
Total	$96 (0.47%)	$1442 (0.41%)	$2849 (0.39%)

Dollar values given in billions (2013 USD, PPP).

2015.[34] As the VLW approach includes nonmarket welfare losses, incorporates morbidity in addition to mortality, and for the latter includes long-run losses, the VLW results are larger than the VLO results.

Data Sources

The EPIC model was used with data as supplied by the WHO, with the exception of GDP per capita estimates that were obtained from the International Futures modeling system (http://www.ifs.du.edu/ifs/frm_MainMenu.aspx) and estimates of future capital stock and total factor productivity that were obtained from Penn World Tables.[24] Capital depreciation data were obtained from the World Development Indicators (https://data.worldbank.org/data-catalog/world-development-indicators). Data on labor projections were retrieved from the International Labor Organization (http://www.ilo.org/ilostat/).

The VLO model evaluated 90 LMICs, and 151 countries were initially evaluated with the VLW approach based on region and income classification from IHME. However, only 127 of these countries are identified as LMICs by the World Bank, and these are included in the final analysis. The difference in evaluated countries reflects data availability, as the VLO requires several econometric estimates that are not readily availability for many countries. Results are presented in 2013 international dollars (US dollars [USD], adjusted for purchasing power parity [PPP]). For each approach, countries were evaluated by IHME region and their respective 2015 World Bank income classification.[34]

Results

Value of Lost Output (2015–2030)

A total of 90 low- and middle-income countries were evaluated (Appendix Table 1). The selected neurosurgical diseases are estimated to result in $4.4 trillion (2013 USD, PPP) in GDP losses during 2015–2030, with annual losses more than doubling over the same time (Fig. 1, Table 1). As a proportion of annual GDP, economic losses are projected to disproportionately affect low- and lower-middle-income countries, risking up to a 0.6% and 0.54% loss, respectively, in 2030 (Fig. 2). Stroke and TBI are responsible for 85% of total losses, but there is significant variation by region (Fig. 3).

Value of Lost Welfare (2015)

We assessed 127 LMICs and estimate that these countries experienced $3 trillion (2013 USD, PPP) in economic welfare losses in 2015 (Table 2). Stroke and TBI were responsible for 90% of total economic losses. When expressed as equivalent proportion of GDP, stroke dispro-

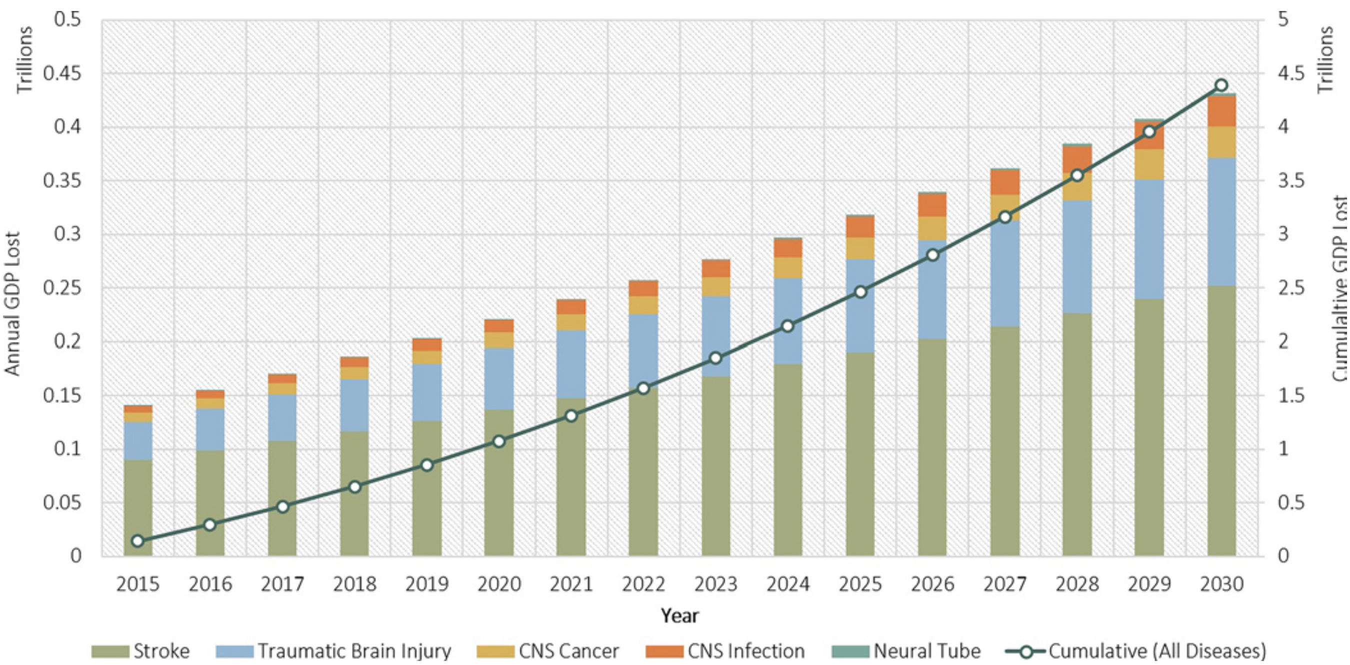

FIG. 1. Projected annual and cumulative GDP lost secondary to neurosurgical disease in LMICs between 2015 and 2030 (given in 2013 USD, PPP). Figure is available in color online only.

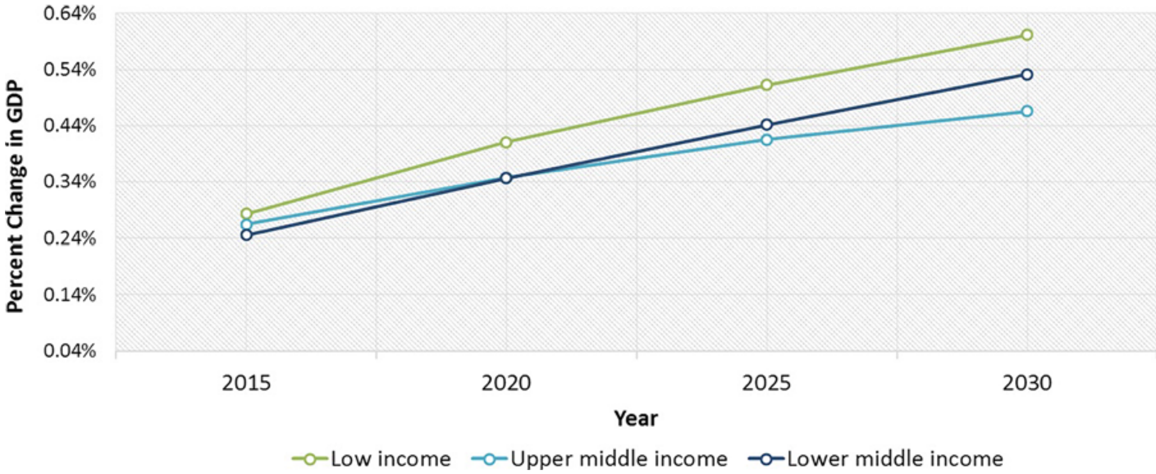

FIG. 2. Projected annual value of lost economic output as a percentage of GDP, stratified by World Bank income classification (given in 2013 USD, PPP). Figure is available in color online only.

portionately affected upper-middle-income countries (4% vs 2% for low-income countries), while CNS infection resulted in 7 times the economic burden in low-income versus upper-middle-income countries (Fig. 4).

Discussion

This study presents an estimate of the economic burden imposed by neurosurgical disease in LMICs using two distinct approaches to evaluate losses in both potential GDP and total economic welfare.

The VLO approach, which assesses market losses between 2015 and 2030, estimates mortality resulting from neurosurgical diseases will account for $4.4 trillion (2013 USD, PPP) in GDP losses in the included 90 LMICs. We project that the economic losses as a share of GDP will not only double over 15 years, but also disproportionately affect low-income countries (Figs. 2 and 3). Low-income countries in sub-Saharan Africa and Southeast Asia are at particularly high risk, with estimates of losses of up to 0.6% of GDP in 2030.

Health and economic growth are mutually reinforcing, and countries can consequently enter virtuous or vicious health-income spirals.[18] The link from income to health through increased spending on prevention and treatment is an often-discussed economic concept. Additionally, a growing body of research has highlighted the role of health not only as an outcome of increased income, but also as an important input.[9,37] The observed correlation between health and income is therefore likely due to a bidirectional and causal relationship between the two.

There are numerous paths in which health and dis-

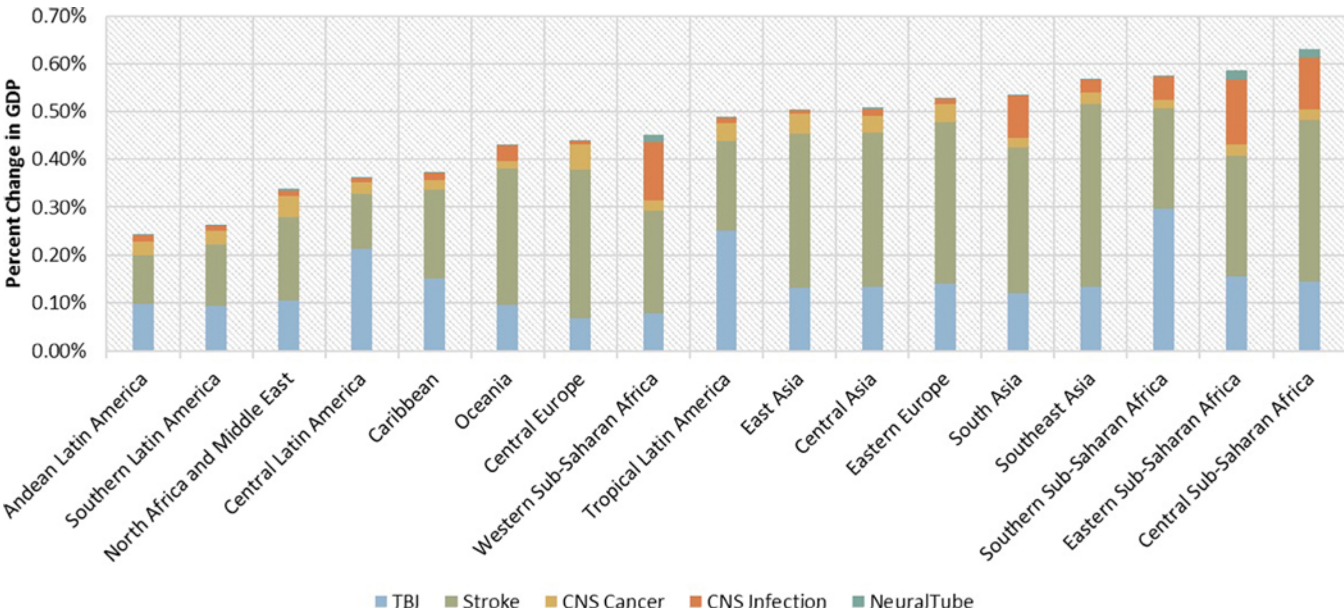

FIG. 3. Projected lost economic output in 2030 as a percentage of GDP, stratified by IHME region and disease category (given in 2013 USD, PPP). Figure is available in color online only.

TABLE 2. Total value of economic welfare losses due to neurosurgical diseases and percentage of equivalent GDP due to disease in 2015

Disease	Low Income	Lower-Middle Income	Upper-Middle Income
CNS cancer	$1 (0.11%)	$30 (0.16%)	$139 (0.35%)
CNS infection	$8 (0.77%)	$86 (0.47%)	$39 (0.10%)
Neural tube defects	$1 (0.07%)	$4 (0.02%)	$11 (0.03%)
Stroke	$19 (1.90%)	$512 (2.80%)	$1605 (4.05%)
TBI	$7 (0.73%)	$125 (0.68%)	$380 (0.96%)
Total	$35 (3.58%)	$757 (4.14%)	$2174 (5.48%)

Dollar values given in billions (2013 USD, PPP).

ease can affect income at the household and societal level. Morbidity results in decreased productivity of the individual worker as well as a lower potential for effective education.[13] Out-of-pocket expenditures for the acute treatment of disease can push households into permanent impoverishment, particularly if they are forced to sell their productive assets.[37] Indeed, some 81 million people annually face catastrophic expenditure accessing surgery.[39] An increased life expectancy can result in an incentive structure beneficial for economic growth. There is more time to capitalize on education, and the incentive for saving for retirement grows stronger, leading to higher national savings, an important driver of economic growth.[30] Improved health also leads to lower fertility, allowing for a higher concentration of resources spent on the education of each child.[30,31]

Some authors have suggested the existence of a high-mortality, high-fertility income trap, as ill health and poverty reinforce each other in a feedback loop. Of note, we estimate low-income countries will incur the largest production losses as measured by the percentage of GDP, suggesting the neurosurgical disease contribution to this feedback loop is particularly important in low-income countries. On the bright side, investments in health have the potential for multiplicative effects, as the improved health is likely to benefit economic growth, which will in turn improve health.

The majority of the GDP losses will result from stroke and TBI, highlighting the need for both preventative measures and increased investment in treatment, including neurosurgery. As stated in the *Methods* section, we made adjustments to account for the fact that not every case of stroke and TBI requires the involvement of a neurosurgeon. Large differences in modeled mortality rates for these diseases between high-income countries (HICs) and LMICs seems to suggest a large part of this burden of disease is avertable. For example, the age-standardized mortality rate for stroke is about 3 times higher in LMICs than in HICs,[46] and our model estimates a difference in TBI mortality rates ranging from 17% to 50%. However, the difference in case mortality rates is likely much larger, as TBI incidence is positively correlated with income through increased vehicle usage.[10] Basic management of TBI and stroke, surgical and nonsurgical, need not be resource-intensive. For example, craniotomy for evacuation of hematoma can be performed safely by trained neurosurgeons in many LMICs (e.g., Ethiopia and Cambodia). Data from Uganda indicate it is possible to perform neurosurgery in an LMIC university hospital setting for as little as US $500, with mean procedure cost ranging from approximately US $300 to US $1200 depending on the complexity of the procedure.[1] Unfortunately, as much as 90% of the population in LMICs do not have access to these and other basic surgical services, often with tragic consequences.[33] *Disease Control Priorities*' (3rd edition) most recent recommendations with regard to essential surgery contains burr hole and shunt placement in its list of essential surgical procedures.[22] While our data appear to suggest a not insignificant burden available to treatment by these two procedures, we also show that a more comprehensive neurosurgical package would be needed to address the full extent of economic losses.

While TBI and stroke account for the majority of the economic burden in every income group, the relative importance of CNS infection is highly correlated with income level; it accounts for 21% of GDP losses in low-income countries, and only 2% in upper-middle-income countries.

Using the VLW approach, we estimate morbidity and mortality resulting from the selected neurosurgical diseases to result in a $3.0 trillion loss in 2015 alone. The VLW method, sometimes referred to as the full income method, attempts to account for both market and nonmar-

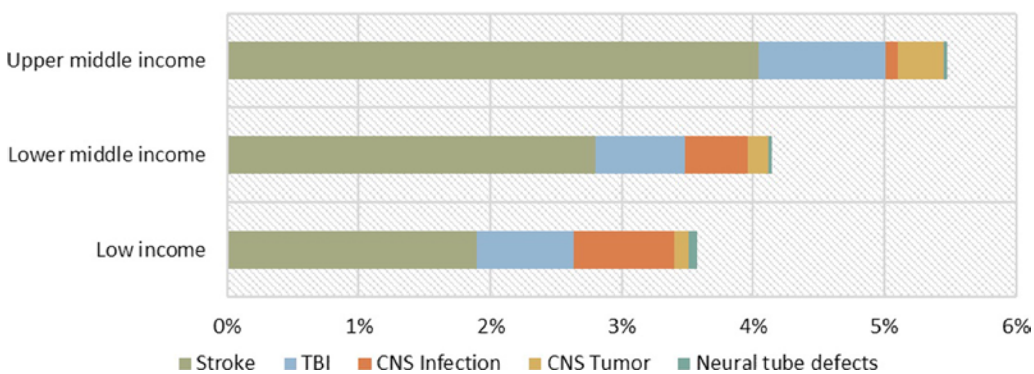

FIG. 4. Total economic welfare losses resulting from neurosurgical disease in 2015, expressed as equivalent percentage of GDP, stratified by World Bank income classification and disease category (given in 2013 USD, PPP). Figure is available in color online only.

ket losses, the latter of which includes the intrinsic value of good health in and of itself. Comparing the economic welfare losses to GDP can give a sense of the scale of the losses incurred; the VLW method estimates losses equaling a startling 5% of GDP. We would caution the reader from interpreting this percentage as lost economic output. The VLW method is inherently meant to measure the impact on general social welfare as valued by the citizens of a country, not to be confused with the rate of GDP growth. However, this distinction does not preclude usefulness of the VLW method. In fact, a major criticism of using GDP to measure development is its failure to include, among other things, a measure of health and well-being. Willingness-to-pay studies have shown most people are willing to pay a large proportion of their income in exchange for reduced mortality risks, and data from such studies underlie the VLW methodology.[28,32,49]

A handful of previous studies have attempted to estimate the global economic consequences of disease using the WHO EPIC model.[2,7,14] Notably, Alkire et al. estimated the global economic consequences of 5 surgical disease categories and projected $12.3 trillion in GDP losses between 2015 and 2030.[7] The scope of that study included some, but not all, neurosurgical burden, and we caution against adding or dividing these results with those of the present study. The only overlap is potentially with trauma and TBI. Bloom et al. investigated the effect of noncommunicable diseases (cardiovascular disease, neoplasm, chronic respiratory disease, mental illness, and diabetes), and estimated $47 trillion in lost GDP between 2011 and 2030,[14] although this estimate included HICs as well. We would caution that differences in scope and assumptions preclude a direct comparison between these studies and our results.

The results of our study need to be interpreted in the light of important limitations. Like most studies of this kind, data availability constraints mean we are reliant on modeled data rather than primarily collected data for our calculations. To account for public health gains and medical advances, we extrapolate based on the trend during the decade preceding the study period. As with any projections about the future, ours contains inherent uncertainty, and disruptive geopolitical events could result in substantially different results.

While the VLW method has clear economic meaning, and allows for estimation of the impact on full economic welfare, applying the method to the low- and middle-income setting is not without methodological difficulties. The lack of willingness-to-pay studies performed in these settings means we must rely on data collected in HICs and apply transformation techniques to adjust for the effect of income on the willingness and ability to pay for mortality risk reductions.[28] There are also limitations in valuing morbidity, including questions about the applicability of VSL techniques to morbidity.[27,47] Due to a lack of available data, we were not able to include TBI-related morbidity in our VLW estimate. The result should, therefore, be interpreted as a conservative lower-bound estimate. Similarly, the exclusion of degenerative and traumatic spine diseases from our analysis would underestimate the welfare losses in the VLW model given that neck and low-back pain are the leading causes of disability in most countries.[34] Finally, the use of a survey to adjust our burden estimates could bias our results upwards if survey respondents overestimate the proportion of diseases that require neurosurgical intervention.

Studies of economic burden should not be used in isolation to prioritize interventions, and our results should be interpreted in light of studies of cost-effectiveness.[20,47] The only such study identified in the literature evaluated treatment for pediatric hydrocephalus, and found it to be cost-effective.[44] In comparison with burden of disease studies, such as measuring lost DALYs, studies of the economic burden of disease can help policymakers more directly compare the cost of increasing access to care to the economic consequences of the status quo. This additional dimension may be of more interest to financial policymakers than studies that only report disease burden as such.

There is significant opportunity for future research in global neurosurgery that would complement our findings. We would suggest that additional cost-effectiveness studies of neurosurgical interventions are crucial for decision-makers. Estimates of the burden of neurosurgical disease, as well as the proportion avertable by prevention and treatment, would also be immensely valuable.

Conclusions

Our study finds that there is a significant economic impact of neurosurgical diseases in LMICs. If cost-utility studies of neurosurgical care in LMICs continue to suggest that it can indeed be cost-effective, previous dogma deeming neurosurgery too complicated and expensive for resource-limited settings would be significantly challenged, especially when accounting for the downstream effects on economic growth as presented in this study. The magnitude of economic losses due to neurosurgical diseases in LMICs provides further motivation for action, beyond the already compelling humanitarian reasons.

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Supplemental Information
Online-Only Content
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