The Economics of Surgery in Low Income Countries

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The Economics of Surgery in Low Income Countries

By

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“Knowledge is like a garden; if it is not cultivated, it cannot be harvested.”

African Proverb

“If you think you are too small to make a difference, you haven’t spent the night with a mosquito.”

African Proverb

“In all my work, I try to say – ‘You may be given a load of sour lemons, why not try to make a dozen lemon meringue pies?’”

Maya Angelou

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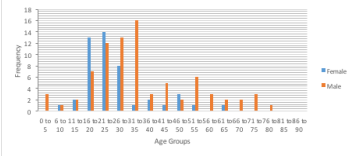
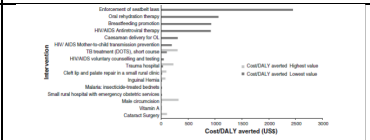
List of Publications

I	Grimes CE, Billingsley ML, Dare AJ, Day N, George PM, Kamara TB, Mkandawire NC, Leather A, Lavy CB. The demographics of patients affected by surgical disease in district hospitals in two sub-Saharan African countries: a retrospective, descriptive analysis. SpringerPlus 2015 4: 750
II	Grimes CE, Henry JA, Maraka J, Mkandawire NC, Cotton M. Cost-effectiveness of Surgery in Low- and Middle-income Countries: A Systematic Review. World Journal of Surgery 2014 Jan;38(1):252-63
III	Grimes CE, Mkandawire NC, Billingsley ML, Ngulube C, Cobey JC. The cost-effectiveness of orthopaedic clinical officers in Malawi. Tropical Doctor. 2014, 44 (3) 128-134.
IV	Grimes CE, Law R, Dare AJ, Day N, Reshamwalla S, Murowa M, George PM, Kamara TB, Mkandawire NC, Leather AJM, Lavy CBD. The Cost-Effectiveness of Two Government District Hospitals in sub-Saharan Africa. World Journal of Surgery 2017 March 27 [epub ahead of print]
V	Grimes CE, Quaife M, Kamara TB, Lavy CBD, Leather AJM, Bolkan HA. The Economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone. In press.

Thesis at a Glance

Question	Method	Results	Illustration	Conclusion
I: Does surgical disease predominantly affect an economically active population in low income settings?	A retrospective descriptive analysis of all surgical admissions for two rural sub-Saharan government district hospitals.	16-35 year olds accounted for 57.3% of surgical admissions in Sierra Leone and 53.5% in Malawi.		Most people affected by surgical disease presenting to a district hospital are young adults.
II: Is surgery cost-effective in low and middle income countries?	Systematic review.	Analysis of 27 studies was performed.	 Fig. 2 Cost-effectiveness of surgical interventions compared with other public health interventions	Surgery is highly cost-effective compared with other global health interventions.
III: Is the orthopaedic clinical officer training programme in Malawi cost-effective?	Retrospective logbook review using a convenience sample of seven district hospitals in Malawi.	Overall cost-effectiveness was US$92.06 per DALY averted.		Training of clinical officers in orthopaedic surgery is very cost-effective.
IV: Are government district hospitals cost-effective?	A retrospective analysis of all surgical admissions for two rural sub-Saharan government district hospitals.	Total cost per DALY averted was 26 (range: 17-66) for Thyolo district hospital in Malawi and 363 (range: 187-881) for Bo district hospital in Sierra Leone.	**Table VI: Overall Cost Effectiveness per annum** Method / Cost/DALY averted Malawi / Cost/DALY averted Sierra Leone Baseline (local life expectancies) 26 363 WHO Methodology – no age weighting/ discounting 39 465 WHO Methodology – with age weighting and discounting 66 881 Baseline using ideal life expectancies 17 187	Government district hospitals are highly cost-effective.
V: What is the macroeconomic loss to Sierra Leone from the unmet surgical need?	Calculation of lost DALYs from death and disability in 2012 then modelled using three different approaches to estimate unmet economic loss.	Depending on the economic model used, the cumulative losses are between US$1.1-3.8 billion. The incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80% were calculated to be between US$360 million – US$2.9 billion.	**Table V: Incremental losses averted by scale up of surgical provision compared to current met need** Incremental economic losses averted / Scenario 2: 20% met need / Scenario 3: 80% met need / Scenario 4: 50% met need GNI/capita (ppp) $191,900,891 $1,151,405,348 $671,653,120 Earnings forgone (YLY only) $60,154,488 $360,926,928 $210,540,708 Value of a statistical life approach $493,778,864 $2,962,673,184 $1,728,226,024	There is a huge macroeconomic loss to the economy from death and disability as a result of surgically treatable disease.

Summary

Introduction

Global surgery is a slowly emerging field in global health. In 2006, the World Bank published a chapter on Surgery in the second edition of Disease Control Priorities for Developing Countries (DCP2)[1] which used a survey of 18 surgeons to estimate the disability-adjusted life years (DALYs) attributable to surgically treatable conditions. The rudimentary methodology used in this study attracted widespread attention. Since then, efforts have been made to better quantify the burden of surgical disease that is currently untreated, and to gain political traction and raise the profile of surgery within global health. The publication of the Lancet Commission on Global Surgery[2] (LCoGS) and the Essential Surgery volume of the third edition of Disease Control Priorities for Developing Countries (DCP3)[3], together with the passing of the World Health Assembly Resolution on Essential and Emergency Surgical Care[4] led to 2015 being described as a 'banner year' for global surgery[5]. Further progress was achieved in 2016 with the incorporation of the first of the LCoGS indicators into the World Bank Development Indicators[6], and then, this year, with Zambia producing the first national surgical plan, with other countries like Ethiopia creating strong national programs to improve the quantity and quality of surgical care.

The optimism within the global surgery community has not yet translated into any health gains for the poor and marginalised in LMIC settings, partly because only a few countries have begun to develop policies for surgical care, but crucially also because the funding commitments from the international community and national health budgets are not forthcoming. This inertia is unlikely to be overcome without better evidence to inform policy makers and without political prioritization for surgery within the donor community and by Ministers of Finance. At present, the evidence for the enormous burden of death and disability which could be prevented by access to essential surgical care in low and middle income countries (LMICs), is largely based on modelled data, with almost no primary national

population level data on surgical conditions. The same applies for the economic data – it is largely based on modelling of the macroeconomic impact of untreated disease[7] and modelling of the financial investments required to scale up care[8].

The motivation behind these different but related publications was the conviction that in order to realize the vision of universal access to surgical and anaesthesia care globally, there is a need to move from modelled data to primary and country specific data. This thesis brings together five papers all centred around the question: 'is there any financial incentive for investing in the provision of surgical care in low income countries?'

Scope

Paper I

Papers I and IV were derived from the same data set: a retrospective review of all hospital admissions in two rural government district hospitals in sub-Saharan Africa, using a 3-month sample from the wet season and a 3-month sample from the dry season. In Paper I, a descriptive analysis of the patient demographics (age and gender), diagnoses and procedures was performed to test the hypothesis that surgery predominantly affects young adults. Young adults aged between 16-35 years accounted for 57.3% of all surgical admissions in Sierra Leone and 53.5% in Malawi. This may have economic implications but may simply reflect the population pyramids of these countries.

Conclusion: Hospital data suggests that surgical disease affects a significant proportion of young adults in these two low-income countries at an age when they are likely to be potentially economically most active. This may simply be, however, that these countries have young populations.

Paper II

Paper II is a systematic review of all articles published related to the cost-effectiveness of a surgical intervention or platform in LMICs. PubMed and EMBASE databases were searched and relevant data was extracted and presented. The cost-effectiveness of the surgical intervention or platform from 27 papers was compared with other public health interventions including oral rehydration therapy, breast feeding promotion and highly active anti-retroviral therapy for HIV. The study shows surgery is highly cost-effective as a global public health intervention.

Conclusion: Surgical procedures are highly cost-effective in LMICs.

Paper III

Paper III studies the cost-effectiveness of training Orthopaedic Clinical Officers (OCO) who are non-physician clinician (NPC) surgical providers in Malawi, using a

convenience sample of seven district hospitals, based on the practicality of travel to these hospitals and the quality of data entry within the logbooks. The logbooks were retrospectively reviewed for three months in the dry season and three months in the wet season. DALYs were calculated using the GBD estimates for life expectancy and disability weights, introducing weights for likely threat to life or permanent disability and likely effectiveness of treatment. Costs were calculated for the training and salary of the OCO along with procedural and hospital costs. The overall cost-effectiveness was US$92.06 per DALY averted with a mean per hospital of US$138.75 (95%CI: US$69.58-207.91). An additional finding was the high proportion of patients that were under the age of 15 (63%).

Conclusion: Training NPCs to provide essential orthopaedic care in government district hospitals is highly cost-effective.

Paper IV

In Paper IV, data was extracted and DALYs were calculated based on the diagnosis and procedures undertaken. Estimated costs were obtained based on the patient receiving ideal treatment for their condition rather than actual treatment received. Total cost per DALY averted was 26 (range: 17-66) for Thyolo district hospital in Malawi and 363 (range: 187-881) for Bo district hospital in Sierra Leone.

Conclusion: Government district hospitals are highly cost-effective.

Paper V

In Paper V, primary data on all operations performed in Sierra Leone in 2012 from all surgical providers (government, private for profit and private not for profit) was analyzed and DALYs from death and disability averted were calculated. Estimates of met and unmet need were used to model the cumulative lost costs to the economy using three different modelling approaches and the potential incremental averted costs if surgical care was scaled up. Depending on the economic model used, the cumulative losses are between US$1.1-3.8 billion. The incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80% were

calculated to be between US$360 million – US$2.9 billion. This paper was joint first authored with a health economist colleague.

Conclusion: There are significant country-specific macroeconomic costs from lack of surgical care that may be avertable through scale-up of surgical services.

Abbreviations

CEA	Cost-Effectiveness Analysis
DALY	Disability-Adjusted Life Year
DCP2	Disease Control Priorities for Developing Countries. Second Edition.
DCP3	Disease Control Priorities. Third Edition.
GBD	Global Burden of Disease
GDP	Gross Domestic Product
ICER	Incremental Cost-Effectiveness Ratio
LCoGS	Lancet Commission on Global Surgery
LMIC	Low and Middle Income Country
LYS	Life Years Saved
MSF	Medecins Sans Frontieres
NPC	Non-Physician Clinician
OCO	Orthopaedic Clinical Officer
SDG	Sustainable Development Goal
UHC	Universal Health Coverage
USD	United States Dollar
WHO	World Health Organisation

Introduction

Global Surgery in context

Public health has traditionally been concerned with prevention of disease and promotion of health. Surgery has been regarded as primarily concerned with treatment once disease has occurred, rather than with prevention. Nevertheless, surgery is important in public health terms because it reduces death and disability from injury, obstetric complications, abdominal and extra-abdominal diseases and elective conditions such as hernia, clubfoot and cataract[1]. Although surgery has been described as the ''neglected stepchild'' of public health[9], in recent years, and with increasing understanding about the burden of death and disability from surgical conditions, there has been increasing interest in arguing for surgical care to be part of a comprehensive health strategy[2 10 11]. Surgery cross-cuts all of medicine in that all disease categories require the services of a surgeon at some time[12]. It is difficult, therefore, to imagine how a comprehensive health strategy can be built without incorporation of surgical care. In 2014, Jim Kim, President of the World Bank described surgery as "an indivisible, indispensable part of health care and of progress towards universal health coverage"[13]. From an ethical point of view, it has also been argued that access to essential surgical care is part of the basic human right to health[14].

Burden of Surgical disease

Within the global health community, surgery has suffered for many years from three main myths – that the surgical disease burden was low, that the costs were too high and that delivery of care was too complex[15]. A survey of 18 surgeons using a best educated guess method in DCP2, published in 2006, estimated that surgery accounted for 38 DALYs per 1000 population in Africa[1] a figure which included injuries, malignancies, congenital anomalies, obstetric complications, cataracts and glaucoma, and perinatal conditions. This figure did not include other surgical pathology that may be important, such as infections, wounds, abscesses, septic arthritis, and osteomyelitis or hernias, because of a lack of available data. This study led to further publications to better quantify this burden[16-18], although estimates of

disease burden had been published before but had generated little academic interest[19 20].

After 2006, further estimates of surgical disease burden suggested that an estimated two billion people worldwide have no access to surgical care[21] with the poorest one-third of the world receiving only 3.5% of all surgical operations globally[16]. More recent estimates, however, suggest that surgical conditions cause significantly more deaths per year than those from HIV, TB and Malaria combined. An estimated five billion of the world's seven billion population do not have access to safe surgery when needed[10]. Trauma alone has been estimated to account for nearly 10% of all global mortality[22] and injury for 11% of the global burden of disease[23]. Between 1990 and 2010, there was a global shift from death and disability because of communicable diseases, toward death and disability from non-communicable disease and injury[23]. Wide disparities exist in global surgical care, with 34.8 % of the poorest third of the global population receiving only 3.5 % of all surgical procedures[16]. A minimum number of 143 million more procedures are needed globally each year to meet a minimum threshold of 5,000 procedures per 100,000 population[10].

Universal Health Coverage and the Sustainable Development Goals

Universal Health Coverage (UHC) is the concept that all people have access to the health services they need without suffering financial hardship. There are two main motivations for advocating UHC. The first is that every individual has the right to health. The second is that health negatively impacts not just the individual, but the household and community, and ultimately, the national and international community[24]. Good health is good for economics with both the 1993 World Development Report, *Investing in Health*[25], and the more recent Lancet Commission on Investing in Health[26] emphasising the dividends that can pay off through investment in healthcare. Although there is agreement with the concept of UHC, the practicalities, such as which health services should be covered and how they should be paid for, are hotly debated. In order for UHC to be implemented within any health system, there is a need for political will, sufficient numbers of trained

and motivated staff, adequate resources, good governance and aspirational attitudes[27]. Despite these barriers, several countries have made strides towards implementation of UHC[28].

The Sustainable Development Goals (SDGs) superseded the Millennium Development Goals (MDGs) in 2015[29]. They consist of 17 goals, including world health goals, which were developed through collaboration between United Nation member states. The Lancet Commission on Global Surgery argues that both UHC and the SDGs will be impossible to achieve without safe, timely access to surgical and anaesthetic care[2] and recommended a core package of both planned and emergency procedures as part of UHC. The SDGs do not specifically mention surgery and therefore there have been concerns expressed that the LCoGS target of 80% population having access to essential surgical care by 2030, can actually be met[30]. A review of UHC plans which incorporate surgery showed that many countries do cover aspects of surgery within their health schemes, most commonly obstetric care, but refer to disease categories rather than identify specific procedures and are heavily dependent on out of pocket payments[31].

Social and Economic impact

There is a need within global health research, policy and investment to understand not only mortality and morbidity rates of disease, but also the wider social and economic impacts of disease. This includes the demographic groups most affected[32-34]. The composition of emergency surgical admissions in high-income countries is predominantly disorders of the gallbladder, pancreas and liver, followed by colorectal and upper gastrointestinal disorders. Almost 50% of all emergency admissions in the United States are above the age of 60[35]. This contrasts sharply with demographic and disease patterns in LMICs where the population is young and conditions affecting childhood and early adulthood are still major contributors to the mortality figures. A systematic review of trauma registries in low and middle income countries revealed that 75% of trauma victims are male with a median age of 27[36]. Therefore, it is perhaps even more essential that efforts are made to reduce the burden of disease on this important socio-economic group

to limit the impact both on personal and household income, and on national development and productivity.

Studies on income and economic losses

Several studies have looked at the economic burden and loss of income due to surgical disease. Injuries and especially road traffic accidents are particularly important as they are estimated to account for the largest fraction of avertable DALYs[37]. Road traffic accidents (RTAs) and non-fatal injuries can lead to disability which leads to loss of income with the number of disability days varying with the mechanism of injury[38]. Seriously injured people experience substantial financial and work related impact[39]. Road traffic accidents were estimated to cost Iran 7.2 billion USD in 2010, amounting to just over 2% of its GDP[40] and they have been shown to cause significant death, disability and economic losses in high, middle and low income countries[41]. Kotagal et al (2014) used estimates from the global burden of disease study to calculate the likely savings if mortality from RTA's in low and middle income countries was reduced to that of high income countries. They estimate that 49-52 billion DALYs could be averted each year with a resulting potential economic saving of 758-786 billion dollars per year[42].

Disability caused by congenital, infective or inflammatory conditions also leads to loss of economic productivity[43-45] with functional status being directly related to employment and income[46 47]. Disability has been estimated to profoundly impact national economies[48]. The loss of economic productivity can far outweigh the direct costs of seeking treatment[49]. The burden of such musculoskeletal conditions is expected to increase in coming decades, particularly in LMICs[50] with resulting increases in economic losses.

Surgical disease resulting in disability is common in low income countries. A household based survey in Rwanda found an overall prevalence of musculoskeletal impairment of 5.2% of which 46.3% were classified as mild, 43.7% were moderate and 8.2% were severe[51]. Within this study, 31.3% were due to trauma and 11.5% were congenital. Groen et al (2012) survey of untreated surgical conditions in

Sierra Leone found that 28% of those reporting conditions in need of surgical care had an acquired deformity, with 3% having a congenital deformity, presumably resulting in some degree of disability[17]. Hernias are extremely common in Africa with 16-20% of men with a hernia being unable to work and this may be why they are associated with a lower socioeconomic status[52-54].

We would therefore expect that providing people with surgical care should increase both personal and household income, as well as national wealth. There is some evidence that this is the case. For example, the Lancet Commission on Investing in Health calculated that there is approximately US$9-20 return on every US$1 invested in health. Jamison et al estimated a benefit: cost ratio of 10:1 for strengthening surgical capacity at the district hospital[55] – for every $1 invested, $10 are generated through improved health and productivity. There is evidence that treating cataracts increases household income, quality of life and ability to be involved in income-generating activities as well as reducing poverty and need for assistance[56-60]. However, this may not necessarily be the case - a study in Sierra Leone suggested that some people may not return to work after surgery because of fear for their health[61].

The Role of the District Hospital

It has been argued that investment in district hospitals is key to sustainable, long-term healthcare solutions[62]. District hospitals are often the main providers of surgical care to rural populations, and so improving service delivery would be expected to lead to improvement in overall care to a population, especially in rural areas. Improvement of surgical district hospital care may also have a general effect on health by acting as an "enabler", to raise the overall quality of health care and encouraging patients to seek care for non-surgical conditions[63]. Provision of surgical care at district hospital level should also affect the ability to achieve the sustainable development goals (SDG) and allow proper and full integration of public health "vertical" programmes, thus improving health care overall. A fully functioning local district hospital would have further, much wider ranging benefits such as easy access to medicines and vaccinations, as well as easier follow up.

DCP3 regards district hospitals as key to strengthening surgical care, or universal coverage of essential surgery (UCES), as they are probably highly cost-effective[11]. Provision of essential surgical procedures, largely at district hospitals, could avert an estimated 1.5 million deaths per year, or 6-7% of all avertable deaths in LMICs[11].

Cost-effectiveness studies to date have not assessed the cost-effectiveness of government district hospitals. Four studies have been performed[64-67], but all of these were in non-governmental sector hospitals, and three out of the four of them did not provide obstetric care. Overall, the cost-effectiveness for non-governmental trauma hospitals was US$32.78-223 per DALY averted. The exclusion of obstetric care is crucial as obstetric care was shown to be the source of the highest number of averted DALYs in the McCord study[64]. Debas et al (2006) estimated that the ideal first-level referral hospital should be highly cost-effective at an estimated US$33 per DALY averted for sub-Saharan Africa[1]. As part of developing the economic argument for investment in surgical care, it is therefore of interest to perform a cost-effectiveness analysis of government district hospitals in sub-Saharan Africa.

The Papers

The papers include one systematic review of cost-effectiveness studies, one paper on the cost-effectiveness of training non-physician clinicians in provision of basic surgical care, one paper on the demographics of patients with surgical illness in a low-income country setting, one paper on the cost-effectiveness of government district hospitals in sub-Saharan Africa and one paper on the macroeconomic impact from death and disability of untreated surgical disease in a single country.

Aims

Overall

To investigate economic perspectives under-pining provision of surgical and anaesthesia care in LMICs to determine whether there is a financial argument for investment in surgical care.

Specific

Paper I

To describe the demographics of those affected by surgical disease in district hospitals of two sub-Saharan African countries to determine if surgical disease predominantly affects young adults.

Paper II

To review published literature on the cost-effectiveness of surgical interventions and compare these to standard public health interventions.

Paper III

To determine the cost-effectiveness of the Orthopaedic Clinical Officer programme in Malawi.

Paper IV

To determine the cost-effectiveness of two government district hospitals in sub-Saharan Africa.

Paper V

To estimate the costs to the Sierra Leone economy from death and disability which may have been averted by surgical care using a 2012 data-set.

Methods

Papers I and IV: District hospitals in sub-Saharan Africa

Two busy rural hospitals in Sierra Leone and Malawi were selected for the project where most clinical work and all surgical work was undertaken by locally trained staff. Both hospitals provided some surgical care, and the theatre, outpatient and ward logbooks were analysed. The two hospitals allowed a comparison between Southern and West Africa. Paper 3 is descriptive, studying the demographics of those affected by surgical disease, with the hypothesis that surgical disease predominately affects the young adult population. Paper 4 calculates the DALYs averted by the hospitals based on the diagnosis and procedures undertaken. Estimated costs were obtained based on the patient receiving ideal treatment for their condition rather than actual treatment received.

Thyolo District Hospital in Malawi

Malawi is a landlocked country in East Africa and has a population of approximately 15 million of which 85% live in rural areas. Thyolo District Hospital in southern Malawi is a 350-bed government district hospital catering for a population of approximately 600,000. It has one doctor, the District Medical Officer, who has the responsibility for the overall running of the hospital with most of the clinical work being performed by 20 clinical officers supported by nursing staff. It has two operating theatres, but only one that was in regular use during the period covered by this study. In Malawi, medical and surgical treatment is free at the point of delivery and patients therefore do not have to pay for equipment, patient stay, or any costs associated with their care including the operative procedure.

Bo District Hospital, Sierra Leone

Sierra Leone in West Africa, has a population of approximately 7 million with 60% of the population living in rural areas. Bo District Hospital in Sierra Leone is a 450-bed government district hospital catering for a population of approximately 600,000. It has two operating theatres, but at the time of data collection, only one was in use. Two doctors, called medical officers, provided surgical care, supported by several

surgical nursing staff. In Sierra Leone, although health care is free at the point of delivery for under 5's, pregnant and lactating women, all other patients must pay for costs related to bed stay, equipment, supplies, medications, investigations and the operation. The costs of the operation are divided into minor, intermediate and major procedures and are set centrally by the government each year.

Data Collection

Whole hospital inpatient data was collected retrospectively from two separate three-month periods, representing rainy and dry seasons, through rigorous review and analysis of logbooks from all wards and theatres. The different sets of data were cross-referenced and, where possible, duplicates removed. In Sierra Leone, all hospital data was collected for the months of July to September 2012 inclusive and February to April 2013 inclusive to capture both rainy and dry seasons. In Malawi, all hospital data was collected for the months of January to March 2013 and April to July 2013. As rainy and dry seasons differ in the two countries, the months studied were also different. The diagnoses were deemed "surgical" if the condition could be managed by a surgically trained provider. Analysis of the ward log books were used as the source for all surgical diagnoses, and analysis of both the ward logbooks and the theatre logbooks were used as the source for all surgical procedures performed. Most of the obstetric surgical work was transferred from the government district hospital in Bo to the nearby Medicin Sans Frontieres (MSF) hospital at Gondama. For Paper III, we contacted MSF and obtained data from their records for the period studied for the district of Bo for the demographic data paper.

Paper II: Cost Effectiveness of Surgery in Low and Middle Income Countries

In this study, the databases of PubMed and EMBASE were searched using the single search terms and combinations of the search terms ''DALY,'' ''quality adjusted life year,'' ''cost-effectiveness,'' and ''surgery.'' Bibliographies and related citations in PubMed were used to identify additional articles. All titles and abstracts were reviewed. Where doubt existed, full texts were reviewed to determine suitability for inclusion. Articles were included if they detailed the cost-effectiveness of a given surgical intervention of relevance to LMICs (World Bank classification 2011)

using standard metrics such as DALYs, life years saved (LYS), or other applicable metrics used in cost-effectiveness analyses. Articles were excluded if they were not in English, related only to high-income countries, or did not detail costs and related effectiveness. Only peer-reviewed studies were considered. Findings were reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guide.

To facilitate comparison between the studies, all cost estimates were converted to US dollars by using gross domestic product (GDP) deflators and then purchasing power parities (PPPs) (World Health Organisation 2005). Both GDPs and PPPs were obtained from the International Monetary Fund and the Organisation for Economic Co-operation and Development.

The measure of effectiveness used was the DALY, a health metric that describes the morbidity and mortality due to a risk factor or disease in a population and is the standard unit used by the Global Burden of Disease Study[23]. It represents one healthy year of life lost due to early death or disability and is calculated by adding the years lived with disability and years of life lost prematurely. The effectiveness of a surgical intervention is measured as the number of DALYs the intervention averts. The cost-effectiveness is the cost for each DALY averted. Cost per DALY averted was obtained by dividing the total cost of a procedure by the total number of DALYs that procedure averted.

The WHO has published thresholds for determining whether an intervention is cost effective based on work by the Commission on Macroeconomics and Health[68]. An intervention that costs less than the GDP/capita per DALY averted is very cost-effective. An intervention that costs between one and three times the GDP/capita per DALY is still cost-effective, but an intervention that costs more than three times the GDP/capita per DALY is considered not cost-effective. These WHO parameters were used to determine whether an intervention was cost-effective, as well as comparing the published cost per DALY averted figures for each condition.

Paper III: Cost Effectiveness of Orthopaedic Clinical Officers in Malawi

A convenience sample of 7 district hospitals was used and all patients were included who had undergone either a manipulation, an anaesthetic, or both, for an orthopaedic condition as captured through analysis of theatre, outpatient and ward logbooks. The difference between wet and dry seasons was controlled by using a three-month sample from the middle of the wet season and a three-month sample from the middle of the dry season. Set-up costs were estimated using previously published costs of orthopaedic clinical officer training. On-going costs were calculated using costs of equipment required per operation and salary for the orthopaedic clinical officers. Effectiveness was calculated using disability adjusted life years and published disability weights. The total costs and total DALYs were calculated overall and per hospital.

In the published paper, an example of this calculation was used. " For example, a 65-year-old with a forearm fracture which is treated (disability weight of 0.050 as for fracture of radius or ulna; condition fatal < 50% of the time; > 50% chance of permanent cure. 23.29 x 0.050 x 0.3 x 0.7 = 0.245 DALYs averted." In fact, this calculation is incorrect – the healthy life expectancy of a 65 year old male according to the Global Burden of Disease 2010 estimates is 11.6 making the result 0.12 DALYs averted. However the results of the paper itself are not affected as this was an example given in the methodology only.

Paper IV: Cost-Effectiveness of District Hospitals

Calculation of DALYs and Costs

DALY calculation

For each diagnosis, we used a weighting system used by previous authors[64-66 69 70] to determine the likely threat to life without treatment, the likelihood of permanent disability, and the likely efficacy of treatment (Table II). Weights for each operation were estimated using a Delphi method of local doctors and experts in each medical discipline. Specifically, local doctors at both Thyolo district hospital and Bo district hospital were asked for their opinions on a number of diagnoses as to the likely threat to life and the likely efficacy of treatment. In addition, a number of experts

from across specific fields of global health, including mental health, paediatrics, internal medicine and obstetrics /gynaecology were contacted and asked for their opinions on likely threat to life, best practice treatment and likely treatment efficacy for the diagnoses within their area of global health specialty. Disability-Adjusted Life Years averted were calculated using the following formula. For deaths averted, we calculated:

Life Expectancy x Likely threat to life x Efficacy of treatment

This formula is the same that has been used to calculate Life Years Saved in other papers[71]. For those conditions that predominantly cause disability, we used the formula:

Life expectancy x risk of permanent disability x disability weight x efficacy of treatment

We used local life expectancies from the WHO Tables and disability weights from the Global Burden of Disease study[72]. We did not use age-weighting or discounting in the base case analysis in line with the GBD study[23], but did use these in the sensitivity analysis.

Calculation of costs

Capital costs

Actual building costs for Thyolo and estimated building costs for Bo were obtained and depreciated over 20 years using a straight-line method. Equipment costs were estimated at 15% of the building costs and depreciated over 7.5 years[73].

Recurrent costs

For Thyolo, actual salaries were obtained from the hospital for all medical and non-medical staff within the hospital for the financial year beginning 2012. Other recurrent costs, including fuel, utilities and maintenance were obtained from the hospital on an “ideal” level i.e. what was requested from the Ministry of Health

rather than what was obtained. Equivalent estimates for Bo were obtained from reports on health system financing in Sierra Leone[74 75] as actual costs were not available.

Costs of medicines

Government district hospitals in sub-Saharan Africa tend to be underfunded, and therefore "ideal" treatment rather than "actual" treatment was calculated. For each diagnosis, we identified the best treatment according to international or published guidelines. We costed the medicines using the WHO International Drug Price Indicator guide[76 77], and calculated the costs of other materials (e.g. catheters, cannulas and intravenous lines) from local price lists. As far as possible, the full course of treatment for all acute conditions was costed, even if part or most of this would usually be delivered on an outpatient basis (e.g. six months of triple therapy for uncomplicated pulmonary tuberculosis), because partial treatment of such conditions could be detrimental. For chronic, long term conditions such as epilepsy, we costed for inpatient or intravenous treatment and then for two weeks of outpatient oral daily medication, accepting that life-long treatment for disease control would need to be found for each patient but was not part of inpatient hospital costs and therefore not part of our study. We assumed that most infections (e.g. pneumonia) would require minimum three days of intravenous high-dose antibiotics, followed by completion of an oral course, except for severe infections such as meningitis, where costs for a minimum of a one week course of intravenous high-dose antibiotics was calculated. We used a mean cost per major surgical procedure of US$179 (2012 US$), as used by Verguet et al[8] and based on the unit cost of a caesarean section[78].. All costs were converted to international dollars using the Purchasing Power Parity for Sierra Leone and Malawi in 2012[79].

Sensitivity Analysis

We performed sensitivity analyses by recalculating the DALYs averted using the World Health Organisation Guidelines for Cost Effectiveness Analysis[80] with GBD disability weights, with and without age weighting and discounting at 3%, and using ideal life expectancies from the GBD study[81].

Ethics Approval

Ethics approval for both papers was obtained from the Malawi College of Medicine Research Ethics Committee and the Sierra Leone Ethics Committee.

Paper V: Economic losses due to unmet surgical need

This paper was published with a health economist, Matthew Quaife, as a joint first author. MQ built the models used in the paper. My contribution was to ask him to model the economic costs based on the data I provided and my own calculations and to model it using both a human capital approach and a value of a statistical life (VSL) approach. The various possible approaches to VSL were individually researched and discussed and a final approach was agreed. Sensitivity analysis was performed by MQ, again, following discussion. The assumptions of disability on earnings was researched by me and agreed together.

Calculating DALYs

The need for surgery in Sierra Leone was estimated to be approximately 92% based on two cluster randomised, cross-sectional, countrywide surveys[17 82]. Details of all operations performed in Sierra Leone in 2012 from every surgical provider was obtained from a nationwide, retrospective study[83]. Data were excluded if there was no recorded age for the patient, or no recorded operation. The remaining records were then analysed. For each operation, a weighting system used by previous authors[65-67 69-71] was used to determine the likely threat to life without treatment, the likelihood of permanent disability, and the likely efficacy of treatment (Paper V, Table I).

Paper V, Table I: Weightings

Weighting given	Risk of death or permanent disability	Treatment efficacy
0	Condition fatal or permanently disabling <5% of the time	<5% chance of permanent cure
0.3	Condition fatal or permanently disabling 5-50% of the time	5-50% chance of permanent cure
0.7	Condition fatal or permanently disabling 50-95% of the time	50-95% chance of permanent cure
1	Condition fatal or permanently disabling >95% of the time	>95% chance of permanent cure

Weights for each operation were estimated using a Delphi method of local doctors (as described for Paper IV) and experts in each field (Paper V, Table II). Operations were weighted differently depending on whether they were "emergency" or "planned' operations. Those operations where it was unclear whether it was performed as a planned or an emergency operation, were weighted as for a "planned" operation. The occurrence of DALY-causing mortality was calculated by:

N= Life Expectancy x Likely threat to life x Efficacy of treatment

For those conditions that predominantly cause disability, we used the formula:

I = Life expectancy x risk of permanent disability x disability weight x efficacy of treatment

Operations were deemed to either avert death or disability as in table II.

Paper V, Table II: Operations averting DALYs

Primarily death averting	Primarily disability averting	Assumptions of disability on earnings
Amputation	Cataract surgery	60% lifetime earnings lost
Appendicectomy	Cleft lip repair	No impact (no literature found)
Caesarian section	Cystectomy	No impact (no literature found)
Cervical or vaginal laceration	Fracture	88% of earnings lost for one year
Chest tube	Hernia repair (planned/unknown)	18% (16-20%) lifetime earnings lost
Dilatation and curettage	Neonatal surgery (planned/unknown)	No impact (no literature found)
Hernia repair (emergency)	Obstetric fistula repair	97% lifetime earnings lost
Hysterectomy (all)	Urethral stricture dilation	No impact
Laparotomy (all)		
Malignancy		
Manual placenta removal		
Necrosectomy		
Neonatal surgery (emergency)		
Manual placenta removal		
Salpingectomy for ectopic pregnancy		
Ectopic pregnancy		
Tracheostomy		

Calculating economic losses

There are a number of different approaches to calculating macroeconomic losses[84] and therefore we chose to determine economic loss using three different models. The first two of these were human capital approaches and the third using a value of statistical life approach.

Human capital approaches have been widely used in the literature to determine macroeconomic losses due to mortality, based on the economic losses as calculated from national accounts or workforce participation and earnings data[7 85 86]. However, it has been criticised because it is argued that there is more to valuing life and wealth than simply income and accounts. To overcome these limitations, a Value of a Statistical Life approach is used, which is the amount of money a person or society is willing to spend to save one life. This "revealed preference" approach is used to demonstrate the value that society attaches to a life i.e. how much someone would pay for a reduction in risk of mortality[87]. For example, if a welder on an oil rig was willing to accept a pay cut of £1,000 to work on land where the risk of death was 0.001 lower, their VSL would be £1 million (£1,000/0.001). Such methods generate larger values for macroeconomic modelling because they allow individuals to be worth more than their wages.

Therefore, both approaches were used to enable a greater and more rigorous assessment of the macroeconomic losses and to facilitate comparison with other studies where one or other methodological approach is used.

Two separate human capital approaches were used. In the first, mortality was directly related to the gross national income per capita for Sierra Leone (GNI/capita approach). The GNI per capital was multiplied by the number of DALYs averted in each scenario of met surgical need.

One of the problems with the GNI per capita approach is that a few very productive individuals in the country may bias the mean GNI per capita and therefore is not truly representative, particularly in unequal economies such as Sierra Leone.

Therefore a second human capital approach was used after discussion with and on advice of a Health Economist. This used an adapted version of the model by Menzin et al[86] which itself is a model used for emerging and developing economies. This model (more fully described in the paper) estimates the economic losses for a cohort of people of a given age, gender, employment sector and life expectancy based on a weighted average of their economic activity and wage rate. Each gender within our data set was split into five different age groups and the mid-point of each group used to estimate the years of productive life remaining. The strength of using different human capital approaches, indeed of using three different health economic approaches, is that there are strengths and weaknesses of each approach and allows a comparison between different schools of thought and different models.

The nationally representative 2011 Sierra Leone integrated household survey (SLIHS)[88] data was then used to obtain estimates of labour force participation by gender. The proportion of the population not in the labour force, the proportion employed in agriculture, and the proportion in other waged industry was estimated. For both employed groups, SLIHS data was used to calculate the number of hours worked per year and apply earnings and salary data to estimate total annual earnings. This gave a more complex but less unequal estimate of the economic losses from a human capital perspective.

Finally, a VSL approach was used. A number of methods have been used to estimate the VSL in Sierra Leone. For our main analysis, $90,700 as calculated for sub-Saharan Africa by Robinson and Hammit[89], was used as this was the most conservative of the possible estimates. We converted this to its annualised equivalent, the Value of a Statistical Life year (VSLY), as used by Alkire et al[90] and also used in the Commission on Investing in Health[26]. The VSLY is then multiple by the number of DALYs averted.

The literature has not reached consensus on how to estimate productivity losses due to morbidity.[91] Mortality estimates are more straight-forward to calculate as

the productivity ceases to nothing on the death of an individual. The effect of disability is much more uncertain. A 0.5 disability weight, for example, does not necessarily reflect a 50% decrease in productivity. For example, untreated cataracts can result in severe visual impairment. The DALY weight for blindness due to cataracts is 0.6,[92] but this does not mean that productivity will also be reduced by 60%. The extent to which morbidity affects economic productivity will be influenced by the nature of the morbidity and its impact on employment, alongside contextual factors such as the potential for workplace adaptations, for example. We therefore used a pragmatic approach and attempted to obtain condition-specific data from the literature to estimate the proportion of persons with surgically treatable conditions who were unable to work following the development of a condition. Where no evidence of productivity effects were available, we took a conservative approach in assuming that untreated people do not suffer productivity losses.

We used a 5% discounting rate for both costs and benefits and performed both a deterministic sensitivity analysis (using multiple points of discounting) and a probabilistic sensitivity analysis (using 1000 Monte Carlo simulations to assess the impact of parameter uncertainty).

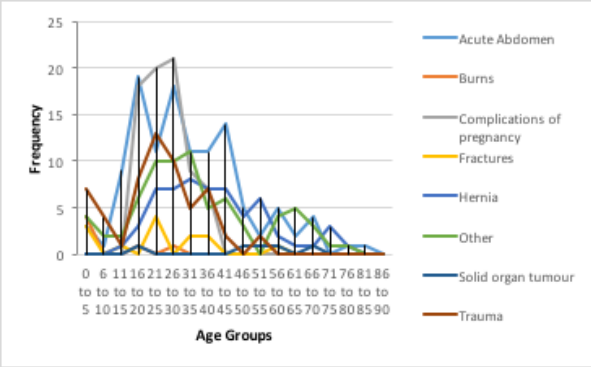
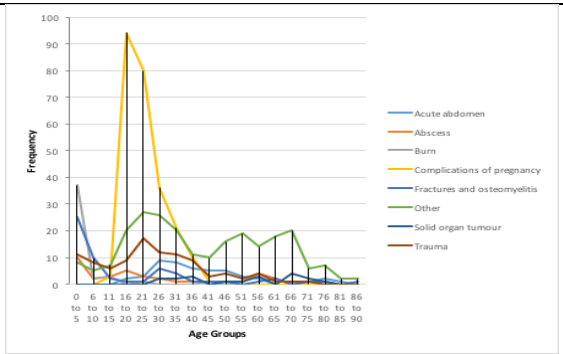
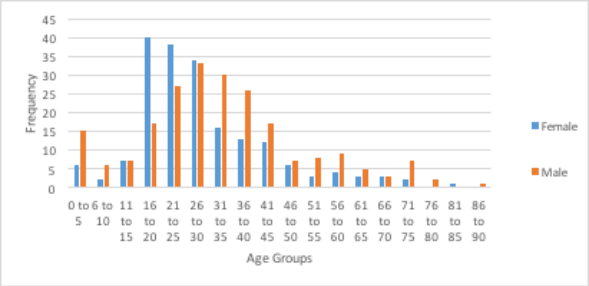
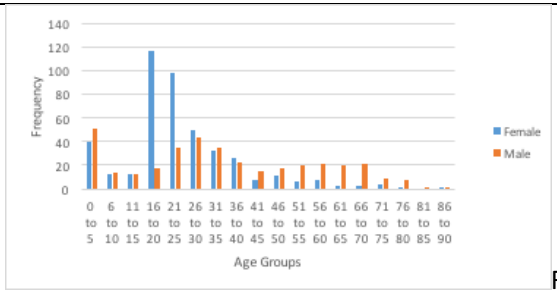
As elsewhere in the literature[85], we compared projected losses with 2014 actual GDP as a useful relative frame to understand the large numbers produced by this model.

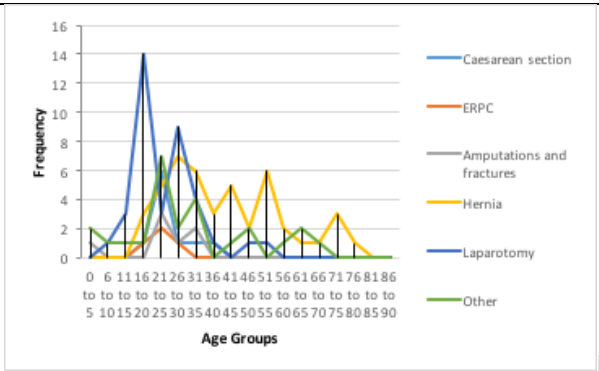
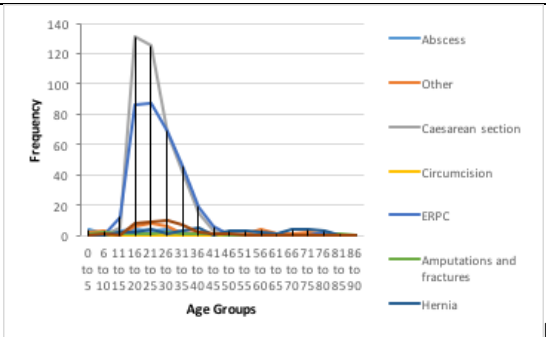
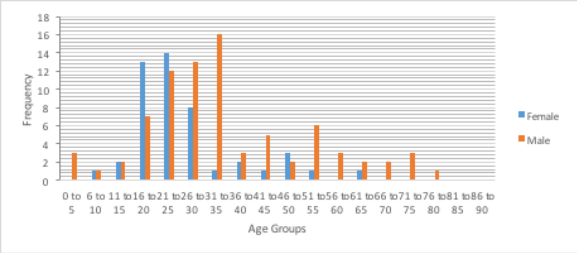
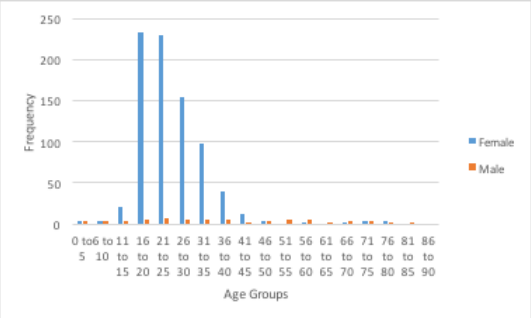
Results

Paper I

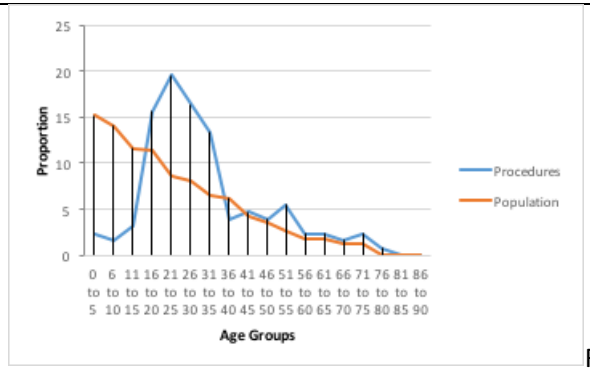
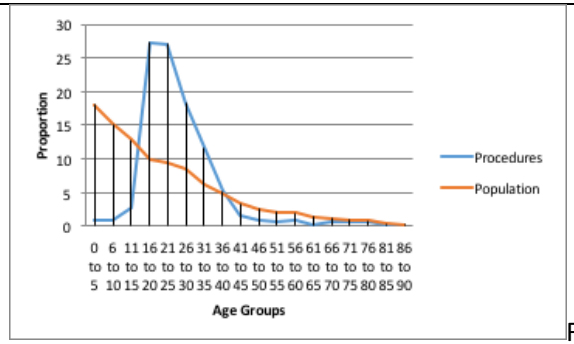
Paper I shows that the majority of patients treated at the two district hospitals in the study were young adults. Figures 1 and 5 show the diagnosis by age group from Bo and Thyolo respectively; Figures 2 and 6 show the gender distribution for the diagnoses; Figures 3 and 7 show the procedure by age group for Bo and Thyolo; Figures 4 and 8 show the gender distribution by procedure. Although the association with age may be argued to be because these countries have young populations, plotting those treated by surgery against the local populations show that this does not explain the demographic observed as shown in Figures 9 and 10, although statistical analysis using the T-test shows that this does not reach significant ($p=0.48$ for Bo and $p=0.49$ for Thyolo).

Paper I, Figures 1-8: Comparative results for Bo District hospital, Sierra Leone and Thyolo District hospital, Malawi: Diagnosis by Age Group; Gender distribution for diagnosis; Procedure by age group; Gender distribution for procedures

	Bo District Hospital, Sierra Leone	Thyolo District Hospital, Malawi
Diagnosis by age group Figure 1: Bo Figure 5: Thyolo	 Fig 1	 Fig 5
Gender distribution for diagnosis Figure 2: Bo Figure 6: Thyolo	 Fig 2	 Fig 6

Procedure by age group Figure 3: Bo Figure 7: Thyolo	 Fig 3	 Fig 7
Gender distribution for procedures Figure 4: Bo Figure 8: Thyolo	 Fig 4	 Fig 8

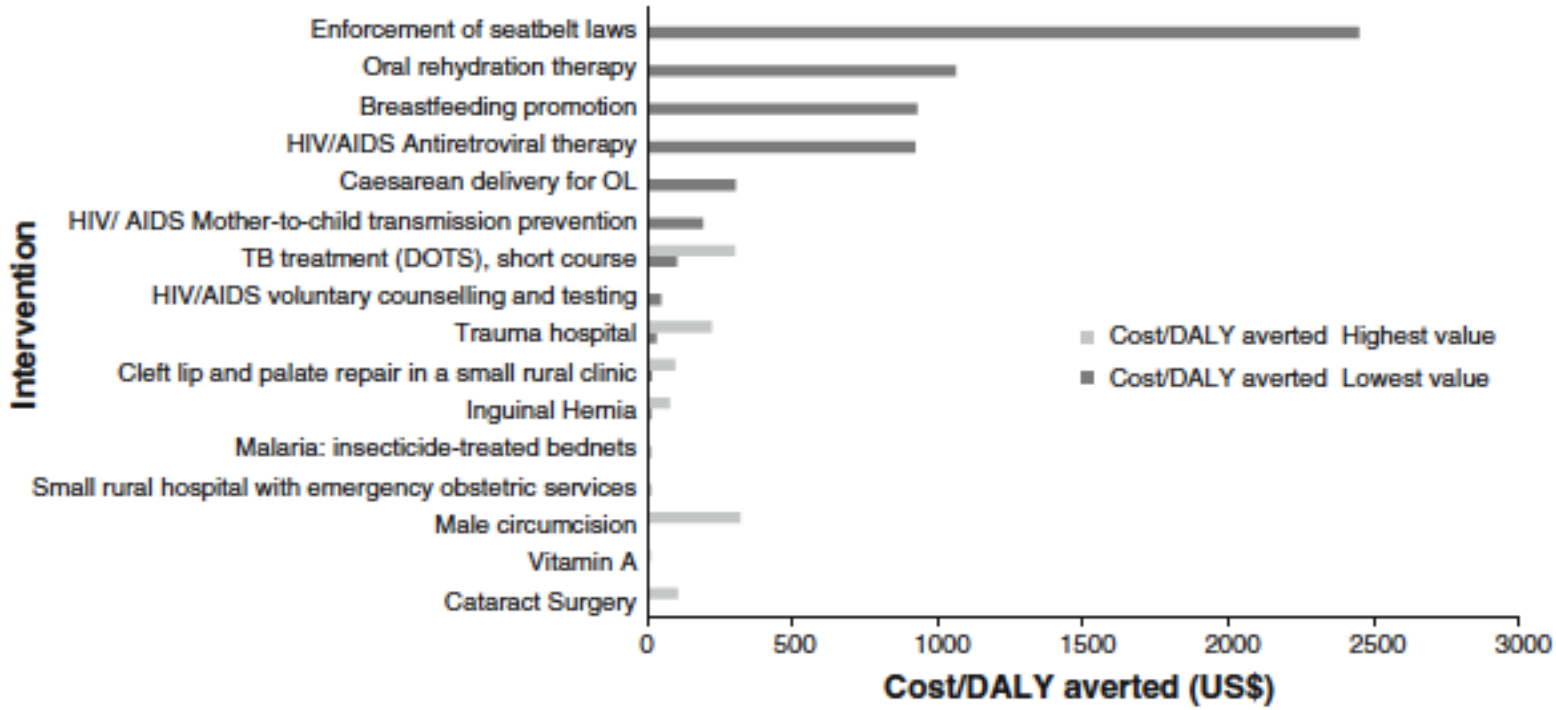
Paper I, Figures 9 and 10: Procedures compared with population demographic in Bo and Thyolo

Procedures performed compared with population demographic Figure 9: Bo Figure 10: Thyolo	 Fig 9	 Fig 10

Paper II

In Paper II, we have shown that surgical procedures have been shown to be very cost-effective compared with some other standard public health interventions. This is demonstrated below in Figure 2, which compares the cost/DALY averted for surgical procedures compared with other public health interventions.

Paper II, Figure 2: Cost-effectiveness of surgical interventions compared with other public health interventions



Paper III

Paper III shows that the training of orthopaedic clinical officers have also been shown to be highly cost-effective forms of surgical intervention with an ability to provide care within local and rural areas in low income countries. The total cost-effectiveness of providing orthopaedic care through the OCO training programme in Malawi was US$92.06 per DALY averted. The mean per hospital was US$138.75 (95% CI: US$69.58-207.91) per DALY averted which is very cost-effective when compared with other health interventions. Of the 837 patients treated 63% were aged <15 years and 36% were in the 'economically active' demographic of ages 15-74 years.

Paper IV

Paper IV shows that the highest proportion of DALYs averted were in paediatrics as shown in Table 4:

Paper IV, Table 4: DALYs averted by specialty in six months

	Number of DALYs Averted (%)	
Specialty	**Thyolo**	**Bo**
Medicine	32780 (34)	2301 (6)
Obstetrics/Gynaecology	20577 (21)	7138 (20)
Paediatrics	40592 (42)	21669 (59)
Psychiatry	534 (1)	21 (0)
Surgery	3361 (3)	5073 (14)
Paediatric surgery	n/a	285 (1)
Total	97844	36487

Calculation of the overall cost-effectiveness demonstrated that government district hospitals are highly cost effective as shown in Table 6.

Paper IV, Table 6: Overall Cost Effectiveness per annum

Method	**Cost/DALY averted Malawi**	**Cost/DALY averted Sierra Leone**
Baseline (local life expectancies)	26	363
WHO Methodology – no age weighting/ discounting	39	465
WHO Methodology – with age weighting and discounting	66	881
Baseline using ideal life expectancies	17	187

Paper V

Paper V shows that the most commonly performed death-averting operations performed were appendicectomy and caesarean section (Table 3). The most commonly performed disability-averting operations were hernia repair and cataract surgery.

Paper V, Table 3: Number of operations performed by procedure

Primarily death averting	**Number of operations in 2012**
Amputation	234
Appendicectomy	1,114
Caesarian section	2,646
Cervical or vaginal laceration	24
Chest tube	35
Dilatation and curettage	508
Hernia repair (emergency)	166
Hysterectomy (all)	218
Laparotomy (all)	815
Malignancy	173
Manual placenta removal	65
Necrosectomy	1
Neonatal surgery (emergency)	13
Manual placenta removal	8
Salpingectomy for ectopic pregnancy	10
Ectopic pregnancy	103
Tracheostomy	8

Primarily disability averting	
Cataract surgery	2,242
Cleft lip repair	2
Cystectomy	16
Fracture	964
Hernia repair (planned/unknown)	3,435
Neonatal surgery (planned/unknown)	5
Obstetric fistula repair	201
Urethral stricture dilation	59
Total	**13,065**

The largest number of mortality DALYs averted in 2012 were in the 20-33 age group, but the largest number of morbidity DALYs averted due to surgery was for the 34+ age group (Table 4):

Paper V, Table 4: Summary of met surgical need in 2012

Age (years)	**Deaths averted in 2012**	**Mortality DALYs averted due to surgery in 2012 (YLL)**	**Morbidity DALYs averted due to surgery in 2012 (YLD)**
1-4	58	1,073	293
5-15	214	3,877	741
16-19	278	4,936	566
20-33	778	13,086	2,225
34+	332	5,173	3,626

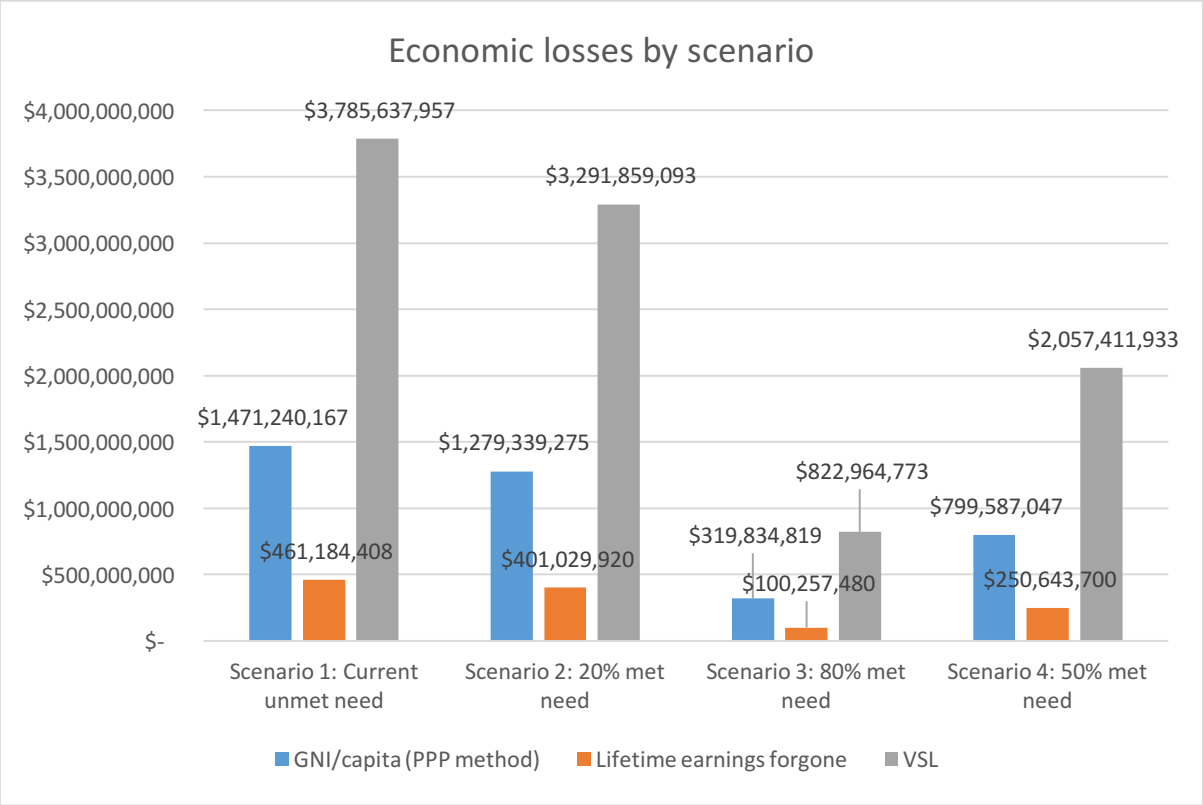
Depending on the methodology used, the calculated incremental macroeconomic costs estimated from unmet surgical disease vary hugely as shown in Table 5. This is demonstrated graphically in Figure 1 and the effect of the one way sensitivity

analysis shown in Figure 2 with Figure 3 demonstrating the results of the probabilistic sensitivity analysis.

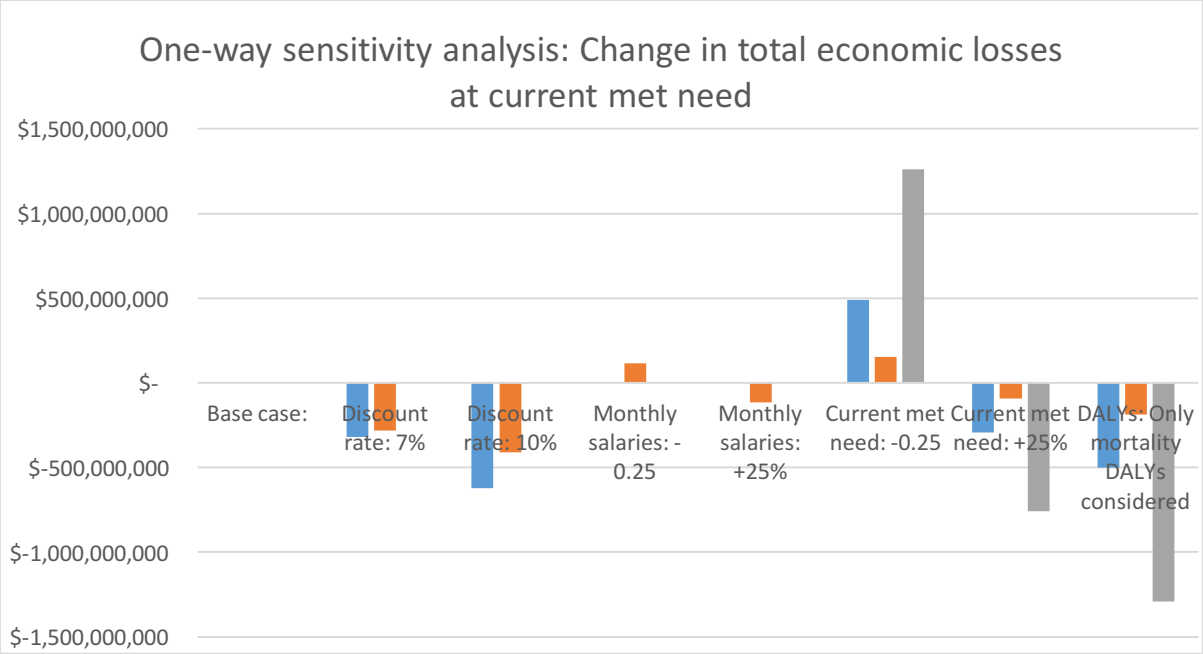
Paper V, Table 5: Incremental losses averted by scale up of surgical provision compared to current met need

Incremental economic losses averted	**Scenario 2: 20% met need**	**Scenario 3: 80% met need**	**Scenario 4: 50% met need**
GNI/capita (ppp)	$191,900,891	$1,151,405,348	$671,653,120
Earnings forgone (YLY only)	$60,154,488	$360,926,928	$210,540,708
Value of a statistical life approach	$493,778,864	$2,962,673,184	$1,728,226,024

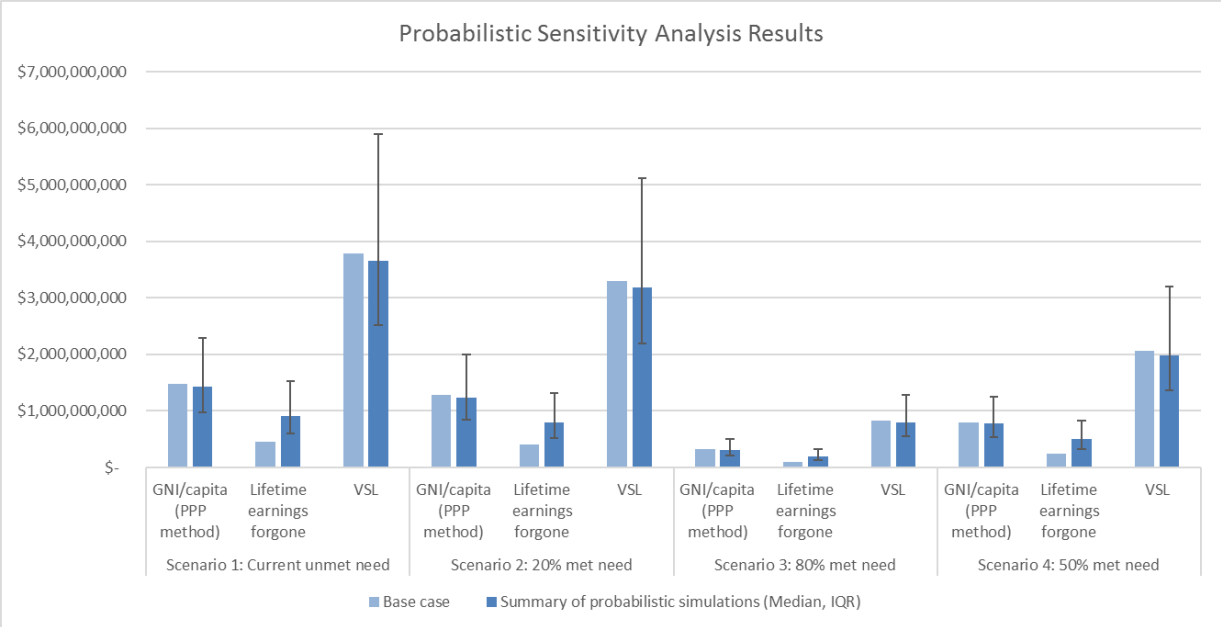
Paper V, Figure 1: Estimated discounted lifetime economic losses due to unmet surgery need by scenario



Paper V, Figure 2: Results of one-way sensitivity analysis



Paper V, Figure 3: Results of the probabilistic sensitivity analysis



Discussion

This research set out to determine whether there is a financial incentive for investing in the provision of surgical care in LMICs. The conclusion from these papers is that there probably is a financial incentive for investment, although each paper has its own methodological constraints.

Paper I

The demographics paper demonstrated that more than 50% of all surgical admissions in two busy district hospitals were aged between 16-35. This suggests, but doesn't prove, that surgical conditions may predominantly affect an economically active population. Most of the young women had obstetric related admissions and it is difficult to be sure what the economic impact of treatment or non-treatment would be for these patients. The observation that many young men present for surgical treatment fits with other observations of trauma predominantly affecting young adult males[36] but does not prove that young people are predominantly affected by surgically-treatable conditions, or that even if this was the case, that this has a significant economic impact. Barriers to access of surgical care have not been well studied, and age and gender issues are hardly mentioned[93]. There may be multiple reasons why young people preferentially present to district hospitals for treatment rather than older people, including perceived value to society, physical strength and stamina. In addition, there is some evidence from Sierra Leone that surgical treatment does not necessarily correlate with return to income-generating activity[61], but more qualitative research is required to further elucidate these issues. Finally, the conclusions of this paper may be too bold – not enough work has been done on met need for these two populations – Bo and Thyolo – to be sure what the actual met or unmet need is. It is likely that met and unmet need various significantly between and within districts within a country due to multiple factors including the health beliefs of the patient population, the access to money and transport, the health facilities available etc. Finally, there was no significant difference when the results were plotted against the population

statistics suggesting that part of the reason that young people present more often to hospital is simply because these countries have young populations.

Paper II

The systematic review suggested that as a public health or global health intervention, surgical interventions are highly cost-effective. A similar systematic review of global surgery interventions was published in the same year and also demonstrated that surgery was highly cost-effective[94]. However, there is a great deal of heterogeneity between the methodology of the papers reviewed and such cost-effectiveness analyses are easily skewed by how and which costs are calculated, as well as how and which benefits are used.

The changing face of cost-effectiveness analysis

The field of cost-effectiveness analysis (CEA) has moved on within global surgery during the time of the publication of these papers. Initial studies of CEA in global surgery gave rough estimates of cost-effectiveness using simple methodologies as used in the orthopaedic clinical officer paper here[64-66 70 95] in order to prove that surgery is cost-effective. However, this methodology is limited as it loses both the patient perspective and the wider system effects and there has since been a move towards more comprehensive methodologies that include this such as extended cost-effectiveness analysis that incorporate these[96]. There has also been an issue in terms of the heterogeneity of the studies and the methodological robustness. One systematic review published looked at the methodological quality of the papers on cost-effectiveness in global surgery using a 10-point Drummond checklist[97]. Only 4 out of the 26 papers reviewed met the criteria[94]. Finally, the purpose of cost-effectiveness analyses has changed. For cost-effectiveness analysis, one intervention needs to be compared to another. Most of the initial papers in cost-effectiveness analysis assumed that nothing already existed (i.e. there was no health system and no possibility of treatment) and therefore compared an intervention against no treatment. In this, they conducted a "shopping spree"[98] whereby the comparison was with other areas of global health e.g. if there is a limited pot of money, should it be invested in surgery, or infectious

disease for example. However, often, something does already exist (even if only within the private sector) and therefore this should be the comparison where available i.e. comparing competing choices. So the question should be what is the cost-effectiveness of a NGO performed hernia repair compared with the cost-effectiveness of locally performed hernia repair. As such, a true incremental cost-effectiveness ratio (ICER) should be calculated where the intervention is compared to the current status quo. A recent paper by Shrime et al, 'Cost-Effectiveness in Global Surgery: Pearls, Pitfalls and a Checklist" has now standardised the approach that should be used for all future cost-effectiveness studies in global surgery[98]. Unfortunately this paper was only published after work on the papers in this thesis had been collated, largely analysed and in some cases, published. This approach groups the analysis into five dimensions – the analytical perspective, cost measurement, effectiveness measurement, probability estimation, valuation of the counterfactual and heterogeneity and uncertainty. In addition, there is also now a database of all cost/DALY papers published within global health[99], but this was also not available at the time of the papers in this thesis.

Paper III

The concept of training orthopaedic clinical officers to enable provision of basic orthopaedic care within district hospitals in a largely rural population is appealing from a service provision point of view. Trauma is a leading cause of global death and disability[100] and predominantly affects an economically important population – young men[36 101]. The results of the paper appear to show that this is highly cost-effective, but is also bound by methodological constraints including: the quality of the data; the sampling; the lack of costs (such as the build and running of an orthopaedic theatre); the associated costs of trained theatre and nursing staff; and the lack of costs from the patient perspective. If we look at the paper from the current checklist for CEA's in global surgery[98], the paper falls short on a number of the dimensions. For example, within 'measuring costs', the costs do not include the patient's direct medical or non-medical costs, or indirect costs. Not all costs to the ministry of health or the hospital are incorporated – the building of the operating theatres are not included neither are costs related to, for example, sterilisation or

linen. The credibility of the measured costs was not checked against other available data, although there was very limited alternative data for comparison. Within 'measuring effectiveness', although the GBD disability weights were used, discounting and sensitivity analysis was not performed in line with current guidelines. Within 'estimating probabilities', a decision tree was not used and the incremental cost-effectiveness ratio – against the counterfactual of the status quo – which in this case would be travel to a central hospital for management under a consultant orthopaedic surgery, was not compared.

Such a paper could be improved methodologically by a number of additional aspects. The costs, direct and indirect, to the patient should be included. The counterfactual scenario of clinical officer performed surgery at the district hospital against consultant surgeon performed surgery at the central hospital should be compared. Although there was some difficulty calculating the costs to the hospital and the ministry for the orthopaedic surgery component only for set up and recurrent costs, a recent paper has comprehensively studied surgical costs in district hospital in Malawi and may prove useful for such further studies[102]. Finally, the cost estimation may be an underestimate – the effectiveness of the orthopaedic clinical officers was only assessed in terms of the operations performed. However, many patients may have been seen and managed non-operatively, and this study does not include this aspect of their scope of practice. Therefore these Clinical Officers may in fact be much more cost-effective than shown. Despite the limitations, this the only paper published that attempts to create an economic rather than a service provision argument for task-sharing.

Paper IV The study on whether government district hospitals are cost-effective shows that, in both cases, they were highly cost-effective, although different in terms of costs. This is probably not surprising – a very busy, underfunded hospital is likely to be highly cost effective. There were numerous methodological issues with this study which have been more fully evaluated in the paper. Retrospective "best treatment" for an individual patient is impossible to truly identify, especially in a resource-poor setting. The costs, which were "actual" in Malawi and

"estimated" in Sierra Leone, were quite different, and there was the overall issue of comparing actual costs with "ideal" treatment. The analysis did not include outpatients, and in Thyolo this was a substantial volume of activity with more than a thousand patients a month. It would be expected that if these had been included, the overall cost-effectiveness would have been even higher, but even this does not prove that a fully funded, fully equipped government district hospital would provide the State with a return on its investment. It suggests that this may be the case, but does not prove it. However, studies on NGO-funded hospitals in low-income countries, have shown that they are cost-effective[64 65 67] and this adds to the evidence that this may be the case.

Again, if this paper is put against the current checklist for cost-effectiveness analysis in global surgery[98], then the paper fails on a number of criteria including the lack of the patient perspective and direct and indirect costs, the standardisation of costs, the credibility of costs (in this we used generic rather than local costs for medicines but local costs for equipment), the use of decision trees, use of the incremental cost-effectiveness ratio against the status quo and scenario analyses. Calculating costs in this paper was particularly problematic, and the difference in the cost-effectiveness of the two hospitals is largely attributable to the difference in costs. Because the funding of the Sierra Leoneon health sector is hugely complex, it was simply impossible to obtain accurate costs for the hospital and therefore a paper was used which included estimates for health system strengthening in Sierra Leone. These costs are likely to be "ideal" costs – what it should cost to provide a full service, rather than the "actual" costs to the government. This has somewhat skewed the analysis because the costs in Malawi were those that were largely actually provided by the government.

Paper V

Finally, the macroeconomic modelling paper, revealed massive cumulative economic losses in Sierra Leone. Like all modelling papers, it relied on several economic assumptions and estimates of morbidity, mortality and likely return to income generating activity, for a wide selection of surgical procedures.

Furthermore, the overall figures are cumulative over an individual's lifetime, and therefore do not estimate what the actual impact on GDP per year would be. This is similar to the Lancet Commission modelling paper[7]. A further study is required – the evaluation of the current situation, what an ideal situation would look like, and the economic costs of scale up and maintenance of a fully functional surgical system in Sierra Leone, similar to that in Zambia (unpublished). Nevertheless, this paper suggests that the economic returns on investment in surgical in Sierra Leone are likely to be substantial.

Cost-effectiveness methodology issues

A number of issues arise when performing cost-effectiveness studies. As no methodology is perfect, there are flaws in the approaches, even if the approach is generally accepted as a suitable method to use. Some of these assumptions and issues are described below.

Disability Adjusted Life Years

The Disability Adjusted Life Year (DALY) was created by Christopher Murray in 1994[103] in order to have a single composite measure which quantified death and disability for any given disease or condition. The aims were two-fold. Firstly, to enable calculation and comparison of the global burden of disease. Secondly, to assist in health policy making by being able to compare the amount of death and disability occurring for each disease or condition and the amount averted per cost between different diseases and conditions. The calculation includes several variables – the life expectancy, a disability weight, discounting and age weighting. By incorporating both death and disability, the DALY overcomes the issue with other measures which only include mortality. Often diseases may cause disability which may have significant economic and quality of life effects on the individual which are ignored by calculations which only involve impact on mortality.

Since its inception, the DALY has been controversial and yet continues to be widely used primarily because of lack of a better alternative which incorporates both death and disability. Although Murray argues that "the premature death of a 40-year-old woman should contribute equally to estimates of the global burden of disease irrespective of whether she lives in the slums of Bogota or a wealthy suburb of Boston"[103], others have questioned whether these two deaths are really comparable. The criticism is that more information is needed about the individual who dies, their roles within their communities and their resources available, than just their age and gender[104]. In addition, the DALY assumes that people who live with disability are of less worth to society than those who do not, a concept which is disputed[105].

DALYs also use standard life expectancies. It is argued that local life expectancies would be better, because standard life expectancies are thought not to be suitable for low income countries where life expectancy is much lower[104]. The use of age-weighting and discounting is also very controversial. These add less value to the people at the extremes of age, and are derived from the human capital approach of economic analysis. It is argued that valuing people in terms of their likely economic contribution to society is ethically problematic in this context.

Disability weights

Disability weights attempt to differentiate diseases causing different levels of disability. They are given a value between 0 (perfect health) to 1 (death) and are created using household surveys and person trade-off questions. Over the years, the methodology of calculating these has changed, with subtle changes in methodology and description leading to significant changes in the burden of disease calculations[106]. Furthermore, the calculation fails to take into account differences between societies and communities of the impact of the disability.

Cost-effectiveness thresholds

The World Health Organisations project, Choosing Interventions that are Cost Effective (WHO-CHOICE), used a threshold whereby any cost / DALY averted which is less than three times the GDP/Capita is deemed "cost-effective" and any cost / DALY averted less than the GDP/Capita is deemed "highly cost-effective". There are criticisms of this approach[107]. Firstly, that cost-effectiveness comparisons differ depending on the local context and locally running programmes and local priorities. Secondly, that more expensive interventions can produce significant health benefits – cheapest per dollar does not necessarily mean that it is the best intervention for a given local context. Too many health interventions can meet the current thresholds – many global health interventions fall into the "cost-effective" threshold making comparisons difficult. It does not incorporate the social willingness to pay for an intervention, which in itself may differ widely between countries and local contexts. Finally, "cost-effective" does not equate to "affordable" and with many cost-effective interventions competing within limited financing contexts, not all those which are cost-effective will get funding.

Nevertheless, it serves as a useful comparator, and like many of these global economic methodologies, exists and continues to be used because of lack of better alternatives.

Purchasing Power Parity methodology

To compare two economies, it is possible to use either market exchange rates, or purchasing power parities. Market exchange rates fluctuate from day to day and are driven by the import and export of traded goods and services. Therefore, purchasing power parities (PPP) are preferred. These compare the cost of living between countries by comparing the purchasing costs of a 'basket' of a given good in each country. The problem with this approach is that the markets both between and within econmomies are diverse and unequal. At a very simple level, the difference between a basket of bread and the cost of a car in one economy is likely to be different in a completely different economy. In addition, cultural, environmental and social factors mean that some 'baskets' will be relatively

cheaper in some economies than in others. Because economies are hugely variable between countries, comparisons are difficult to make accurately.

Economic Arguments and Political Priority

One of the assumptions behind this thesis is that economic arguments lead to political priority. The financial return on health investment has been demonstrated in both the 1993 Investing in Health report[25] and the 2013 Lancet Commission on Investing in Health[26]. However, there is not a direct relationship between demonstrating return on investment and a resulting political will to invest. This is for two main reasons. Firstly, there are other influences on political priority. Secondly, there are difficulties with implementing ideas generated from research and converting them to local health policy and action.

Shiffman's paper on generation of political priority for global health initiatives[108] identified four main factors that shape political priority in global health. The first is *actor power* - the strength of the individuals and organisations concerned with the issue; the second is *ideas* – the ways in which those involved with the issue understand and portray it; the third is *political contexts* – the environments in which actors operate; and finally the *issue characteristics* – the features of the problem. The papers in this thesis contribute to issue characteristics – the economics of the problem, in this case, surgical care.

But does economic evidence itself influence policymaking? A systematic review assessing the impact of economic evidence on policymakers in healthcare found that many factors influence policy. These include the quality and transparency of the studies providing the economic evidence, the transparency and quality of the decision-making process and the clarity of the economic information and the way it was communicated[109]. A qualitative study of stake holders in surgical care and health agenda setting in Papua New Guinea, Uganda and Sierra Leone found that the factors influencing whether surgical care was prioritised on national healthcare plans was influenced by the advocacy of the local surgical community, the political

and economic environment in which the health policy is created, and the influence of international actors, particularly donors[110]. These papers would appear to agree with the Shiffman framework – that evidence alone does not change policy. The context, framing of the problem and power and cohesion of the groups and individuals involved is critical.

Low income country governments face difficult choices over which health services to cover. The 2006 World Bank report, *Health Financing Revisited,* states: "Determining which health services the government should purchase or cover is a difficult decision that low-income countries must face. This decision is usually made on social and political grounds rather than economic reasoning alone. Yet the decision has important implications for the opportunity cost of the resources used and the impact on outcomes and growth."[111]

The analysis by Shawar et al[112] of why surgery has failed to generate political priority despite the high burden of disease found that the surgical community was fragmented, with lack of leadership and failure to capitalise on political opportunities. However, one of the strengths of the global surgical community noted, was of the emergence of economic research, highlighting this as important in contributing towards the generation of political priority in the future.

The other issue is of converting evidence and research into health policy and action. The World Health Organisation acknowledges the significant challenge of taking proven interventions and delivering them across many different health systems and the wide diversity of possible health settings[113]. A review of published articles on health policy implementation in low income countries cites a wide variety of issues which influence implementation. These include the degree of communication and co-ordination between different actors, degree of accountability and responsiveness, decentralisation of the health system, financial protection, degree of match between the intention and reality, perception and understanding of health implementers and users, availability and training of human resources and availability of equipment and infrastructure[114]. A qualitative study of health

experts in Vietnam, Bangladesh and India demonstrated that there was a lack of health economic expertise in the government sector, limited knowledge among policymakers and a lack of close relationship between the researchers and the health authorities[115].

If we accept that economic research is important in influencing political priority, how do we convert such economic evidence into implementable action? One framework to improve implementation of health policy in low income countries recommends the need to firstly improve information, communication and understanding at all levels and secondly improve actor engagement and relationships[114]. There have been few publications on implementation of surgical strategy in low income countries, but one study on trauma systems has demonstrated the need to identify and co-ordinate pre-existing resources, involve local stakeholders, and adapt models to the local context[116]. The challenges for economic researchers in global surgery will be how best to educate policy makers in the economic arguments, how to improve relationships between different actors and economic researchers, how then to derive locally led, implementable policy that produces an economic return on investment, and finally, how to audit such policy both in terms of morbidity and mortality, but also in terms of economic growth.

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The demographics of patients affected by surgical disease in district hospitals in two sub-Saharan African countries: a retrospective descriptive analysis

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Abstract

Background: There is a growing awareness of the importance of surgical disease within global health. We hypothesised that surgical disease in low income countries predominantly affects young adults and may therefore have a significant economic impact.

Methods: We retrospectively reviewed all surgical admission data from two rural government district hospitals in two different sub-Saharan African countries over a 6-month period. We analysed all surgical admissions with respect to patient demographics (age and gender), diagnosis, and procedure performed.

Results: Surgical admissions accounted for 12.9 and 19.8 % of all hospital admissions in Malawi and Sierra Leone respectively. 18.5 and 6.2 % of all hospital patients required a surgical procedure in Malawi and Sierra Leone respectively, with the low number in Sierra Leone accounted for in that many of the obstetric admissions were referred to a nearby Medicins Sans Frontiers (MSF) hospital for treatment. 17.9 and 10.5 % of surgical admissions were under the age of 16 in Malawi and Sierra Leone respectively, with 16–35 year olds accounting for 57.3 % of surgical admissions in Sierra Leone and 53.5 % in Malawi. Men accounted for 53.7 and 46.0 % of surgical admissions in Sierra Leone and Malawi respectively. An unexpected finding was the high level of patients who absconded from hospital in Sierra Leone after diagnosis but before treatment. This involved 11.8 % of all surgical patients, including 38 % with a bowel obstruction, 39 % with peritonitis and 20 % with ectopic pregnancy.

Conclusions: Most people affected by disease requiring surgery are young adults and this may have significant economic implications.

Keywords: Surgery, Low and middle income countries, Demographics, District hospitals

Background

Surgery is increasingly being recognised as an important but neglected part of global health. An estimated 2 billion people worldwide have no access to surgical care (Weiser et al. 2008), with trauma alone accounting for nearly 10 % of all global mortality (Lozano et al. 2012). Furthermore, surgery has been shown to be cost-effective comparable to other routine public health interventions in low and middle-income countries (Grimes et al. 2014; Chao et al. 2014). However, much of the current data pertaining to the burden and consequences of surgical disease are based on best estimates, with many low income countries having no real data as to the burden and impact of surgery within their borders, particularly within rural areas. There is a need, therefore, to substantiate the understanding of global surgery with primary data from the ground.

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There is a trend within global health research, policy and investment to understand not only mortality and morbidity rates of disease, but also the wider social and economic impacts of disease. This includes the demographic groups most affected (Pednekar et al. 2011; Addo et al. 2009; Damasceno et al. 2009; Vedanthan et al. 2014). The composition of emergency surgical admissions in high-income countries is predominantly disorders of the gallbladder, pancreas and liver, followed by colorectal disorders and upper gut. Almost 50 % of all emergency admissions in the United States are above the age of 60 (Gale et al. 2014). This contrasts significantly from demographic and disease patterns in low and middle-income countries where the population is young and conditions affecting childhood and early adulthood are still major contributors to the mortality figures. Therefore, it is perhaps even more essential that efforts are made to reduce the burden of disease on this important socio-economic group to limit the impact on national development and productivity.

The aim of this study was to describe the demographics of those affected by surgical disease by use of primary data from East and West Africa with the hypothesis, based on observation and anecdotal evidence, that surgical disease predominantly affects young adults.

Methods

Two hospitals were selected for the project where the majority of clinical work and all surgical work is performed by locally trained staff. The hospitals covered similar population catchment areas and were within rural areas of East and West Africa respectively. Both hospitals provide some surgical care, and the logbooks were well maintained in order to conduct an analysis.

Settings

Thyolo District Hospital, Malawi

Malawi is a landlocked country in East Africa and has a population of approximately 15 million of which 85 % live in rural areas. Thyolo District Hospital in southern Malawi is a 350-bed government district hospital catering for a population of approximately 600,000. It has one fully qualified doctor, the District Medical Officer, who has the responsibility for the overall running of the hospital with the majority of the clinical work being performed by 20 clinical officers supported by nursing staff. It has two operating theatres, but only one that was in regular use during the period covered by this study. In Malawi, medical and surgical treatment is free at the point of delivery and patients therefore do not have to pay for equipment, patient stay, or any costs associated with their care including the operative procedure.

Bo District Hospital, Sierra Leone

Sierra Leone in West Africa, has a population of approximately 6 million with 60 % of the population living in rural areas. Bo District Hospital in Sierra Leone is a 450 bed government district hospital catering for a population of approximately 600,000. It has two operating theatres, but at the time of data collection, only one was in use. Two MD trained medical officers provided surgical care, supported by a number of surgical nursing staff.

In Sierra Leone, although health care is free at the point of delivery for under 5's, pregnant and lactating women, all other patients have to pay for costs related to bed stay, equipment, supplies, medications, investigations and the operation. The costs of the operation are divided into minor, intermediate and major procedures and are set centrally by the government each year.

Data collection

Whole hospital inpatient data was collected retrospectively from two separate 3-month periods, representing rainy and dry seasons, through rigorous review and analysis of logbooks from all wards and theatres. The different sets of data were cross-referenced and, where possible, duplicates removed.

In Sierra Leone, all hospital data was collected for the months of July–September 2012 inclusive and February–April 2013 inclusive to capture both rainy and dry seasons. In Malawi, all hospital data was collected for the months of January–March 2013 and April–July 2013. As rainy and dry seasons differ in the two countries, the months studied were also different. The diagnoses were deemed "surgical" if the condition should be managed by a surgically trained provider. Any diagnosis, which was not recorded or not legible, was assumed not to be surgical to ensure conservative estimates. The list of "surgical" diagnoses is shown in Table 1. Analysis of the ward log books were used as the source for all surgical diagnoses, and analysis of both the ward logbooks and the theatre logbooks were used as the source for all surgical procedures performed.

Because much of the obstetric surgical work is transferred from the government district hospital in Bo to the nearby Medicin Sans Frontiers (MSF) hospital at Gondama, we contacted MSF and obtained data from their records for the period studied for the district of Bo.

Ethics approval

Ethics approval for data collection was obtained from the Malawi College of Medicine Research Ethics Committee and the Sierra Leone Ethics Committee.

Table 1 Surgical diagnoses included in study

Surgical diagnoses		
Abdominal pain	Keloid scar	Complications of pregnancy including:
Abscess	Lump	Ectopic pregnancy
Acute abdomen	Necrotising fascitiis	Incomplete abortion
Anal fistula	Orchitis	Incomplete miscarriage
Animal bite	Osteomyelitis	Post-partum haemorrhage
Appendicitis	Otitis media	Prolonged labour
Assault	Otitis sepsis	Retained placenta
Basal skull mass	Pancreatitis	Septic abortion
Benign prostatic hyperplasia (BPH)	Paralysis	
Bowel obstruction	Paraphymosis	
Burn	Penile fistula	
Cataract	Peptic ulcer disease	
Cyst	Peritonitis	
Diabetic foot	Priapism	
Diabetic ulcer	Pyomyositis	
Dislocation	Road traffic accident (RTA)	
Ectopic pregnancy	Septic arthritis	
Epididymo-orchitis	Septic finger	
Epistaxis	Septic foot	
Foreign body	Septic sore	
Fracture	Snake bite	
Haemorrhage	Soft tissue injury	
Head injury	Solid organ tumour	
Hepatic abscess	Stabbing	
Hernia	Testicular torsion	
Hydrocele	Trauma	
Infected wound	Unhappy triad of knee	
Injury	Urinary retention	
	Wound	

Results

Surgical admissions as a proportion of total hospital admissions

In Thyolo District Hospital there were 6481 hospital admissions of which 835 (12.9 %) were surgical. In Bo District Hospital, there were 2152 hospital admissions of which 427 (19.8 %) were surgical. Not all surgical admissions required an operation. For example, patients with burns, head injury and assault were admitted into surgical wards, but many were managed conservatively. Conversely, not all patients who underwent a surgical procedure were admitted. For instance, the majority of patients undergoing evacuation of retained products of conception (ERPC) and some patients undergoing caesarean section at Thyolo were discharged home directly from the theatre complex. Analysis and comparison of the logbook data suggested that all other procedures were performed on patients also recorded on the inpatient data.

In Thyolo 898 patients underwent a surgical procedure in theatre. Analysis of the ERPC and caesarean section data showed that only 5 of the 332 patients who underwent an ERPC, and 271 of the 394 who underwent an emergency caesarean section, were admitted. Therefore the admission data does not capture many of the patients who underwent a procedure in theatre. If all patients who had undergone a procedure in theatre had been admitted, the total number of admissions would have been 6931 with 19.4 % of all hospital admissions being surgical and 18.5 % of all hospital patients requiring surgical input. With a population of approximately 600,000, the major operation rate for Thyolo was therefore 299 per 100,000 population per year.

In Bo, 133 patients underwent a surgical procedure. This corresponded to 6.2 % of all hospital admissions over the total 6 month period. As this is likely to be an underestimate as the majority of the maternal surgical work was performed at the nearby MSF hospital in Gondama, we contacted MSF to obtain their obstetric data for that time period. MSF data showed that over this 6 month period 296 caesarean sections were performed, 82 ERPC's, 36 operations for ectopic pregnancy, 8 hysterectomies or oophorectomies and 8 other undefined obstetric or gynaecological procedures. 90.9 % of all obstetric and gynaecological procedures were performed on an urgent basis and 72 % were between the ages of 16–35 (Surgical Activity Reports 2013). Total operations (maternal and non-maternal) for the MSF hospital and for Bo District Hospital combined gave a procedure rate of 231 operations per 100,000 population per year (World Population Prospects 2012).

Absconders in Bo

We recorded 33 (11.8 %) patients, having received a surgical diagnosis, subsequently absconded before receiving treatment. These included 3 of the 8 patients with bowel obstruction (38 %), 7 of the 18 patients with an acute abdomen (39 %) and 1 of the 5 ectopic pregnancies (20 %). This may have been because of the need to pay for hospital admission and any procedures undertaken, or it may be for sociocultural reasons.

Age and gender distribution

Many surgical patients who were admitted did not require an operation. Conversely, some patients underwent a procedure but were not admitted. Therefore, we analysed surgical admissions and surgical procedures separately for Bo and Thyolo. The results are shown in Figs. 1, 2, 3, 4, 5, 6, 7 and 8. A number of patients were excluded from this analysis as there was no age recorded. The number excluded were 5 from the procedure data in Bo, 17 from the diagnostic data in Bo, 25 from the procedure data in Thyolo and 37 from the diagnostic data in Thyolo.

Analysis of the demographics revealed that under 16 year olds accounted for 10.5 % of surgical admissions in Bo, and 17.9 % of surgical admissions in Thyolo, with 16–35 year olds accounting for 57.3 % of all surgical admissions in Bo and 53.5 % of all surgical admissions in Thyolo. Men underwent 63 % of all surgical procedures in Bo but only 7.7 % of surgical procedures in Thyolo, because of the high rate of obstetric surgery in Thyolo which was not present in Bo.

As it was felt that the distribution of disease towards young adults may partly be due to a young population demographic, procedures were also plotted against the population demographics for Bo District Hospital and Malawi using census data (Population and Housing Census 2008; Census for Bo District 2015). The results, shown in Figs. 9 and 10, suggest that the young adult population treated at these hospitals cannot be accounted for by local population demographic alone.

Discussion

Comparison of Bo and Thyolo hospitals

Surgical conditions account for a significant burden of the district hospital work load in low income countries. This was quantified to be 19.4 and 19.8 % of all admissions for these two hospitals in two different countries in east and west Africa. The two hospitals in this study showed different types of procedures and volume based on the skills and facilities available. In Thyolo, few general surgical procedures were performed, but Thyolo did perform a large number of obstetric procedures which were not performed in Bo. This can largely be explained by local access to a larger centre specialising in areas of surgical practice. Conversely, in Bo, few maternal procedures were performed because of a local MSF hospital which offered these procedures free of charge. However Bo did have the facilities and skills to perform a large number of general surgical procedures, such as appendicectomies and non-gynaecological laparotomies which were not available in the same way in Thyolo.

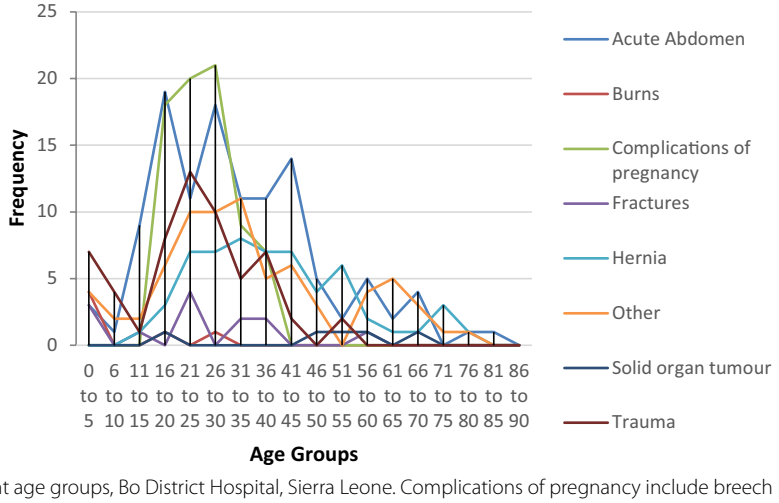

Fig. 1 Diagnoses at different age groups, Bo District Hospital, Sierra Leone. Complications of pregnancy include breech presentation, pre-eclampsia, eclampsia, premature labour, prolonged labour, retained placenta, puerperal sepsis, post-partum haemorrhage, ectopic pregnancy, incomplete abortion, incompletely miscarriage. Acute Abdomen includes abdominal pain, peritonitis, peptic ulcer disease, appendicitis, bowel obstruction. Trauma includes head injury, road traffic accident, assault. Other includes hydrocele, snake bite, wounds, abscesses, urinary retention, anal/penile fistula, septic abrotion, pancreatitis, priapism, otitis media, diabetic foot/ulcer, septic finger, infected wounds, lumps, osteomyelitis, necrotising fasciiis, keloid scar, cyst, unhappy triad of knee, hepatic abscess

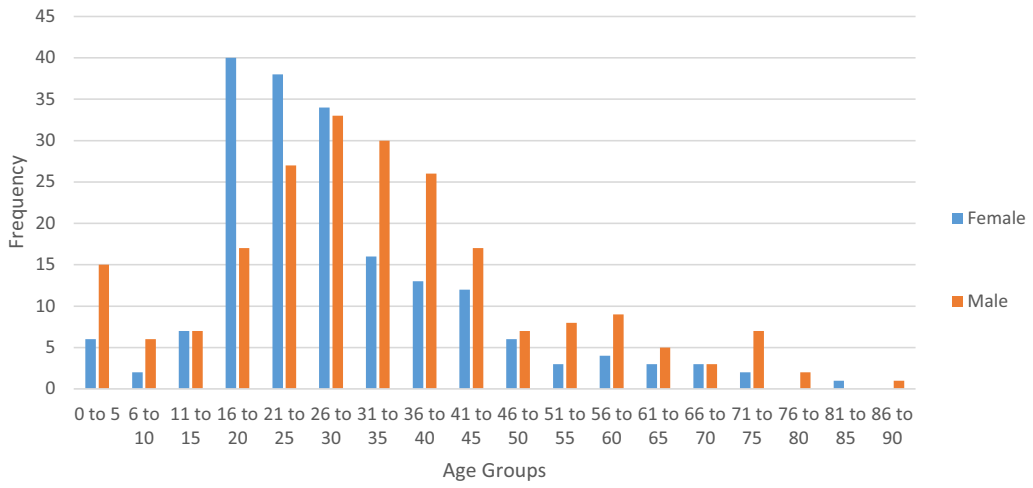

Fig. 2 Gender distribution for diagnoses at Bo District Hospital

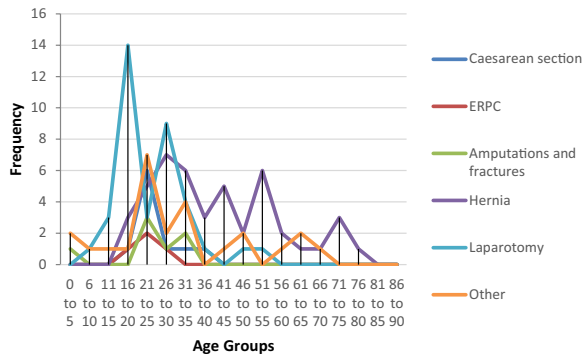

Fig. 3 Procedures performed at different age groups, Bo District Hospital, Sierra Leone. Other: lump excision, hydrocele repair, wound management, abscess drainage. Laparotomy including appendicectomy

Although the two hospitals volumes and procedures differed, the main age groups undergoing surgical treatment were similar. In both hospitals, just over half of all admissions were aged 16–35, with 10–17 % below the age of 16. This cannot be explained just by the age structure in these countries and is likely to be more reflective of the fact that many of these diseases such as appendicitis, obstructed labour, road traffic accidents, trauma and fractures are diseases of young adults. It is possible that young fit adults may be more likely to seek and attend for hospital care.

This study does not take into account outpatient surgical procedures. These would include incision and drainage of abscesses, suturing and/or debridement of wounds, reduction of dislocations and fractures, circumcision,

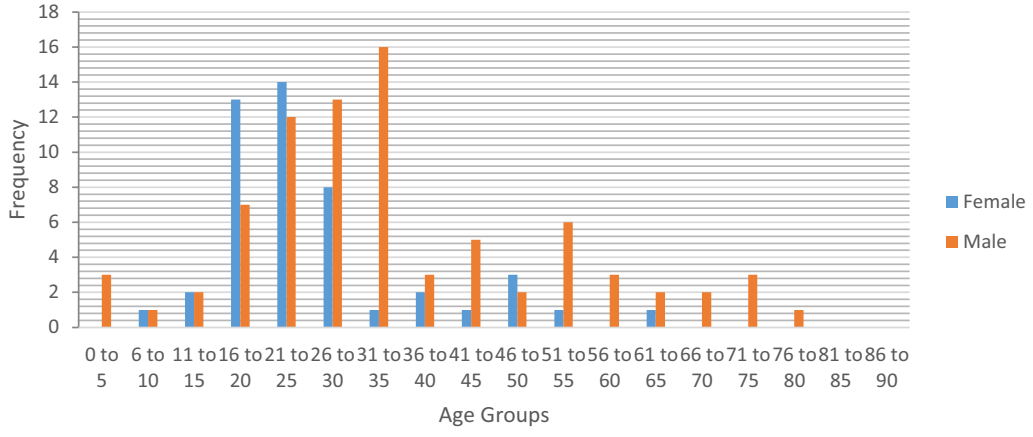

Fig. 4 Gender distribution for surgical procedures at Bo District Hospital, Thyolo

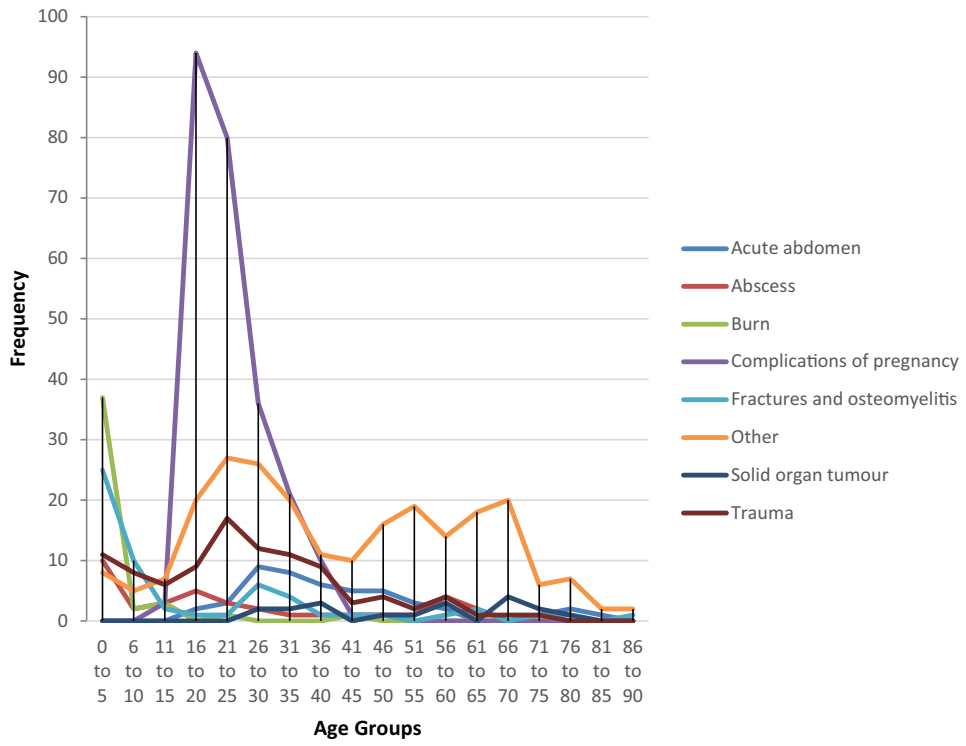

Fig. 5 Diagnoses at different age groups, Thyolo District Hospital, Malawi. Complications of pregnancy including ectopic pregnancy and incomplete miscarriage. Acute abdomen: includes abdominal pain, pancreatitis, peptic ulcer, bowel obstruction. Trauma includes road traffic accident, stabbing, assault and injury. Other: Foreign body, septic sore, septic arthritis, wound problems, hydrocele, hernia, cataract, orchitis, epididymoorchitis, testicular torsion, paraphymosis, pyomyositis, animal bite, benign prostatic hyperplasia, lump, snake bite, soft tissue injury, basal skull mass, paralysis, otitis sepsis, epistaxis, haemorrhage

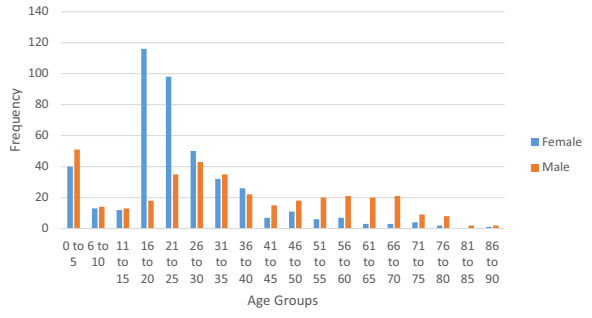

Fig. 6 Gender distribution for diagnoses at Thyolo District Hospital

removal of foreign bodies, child herniotomy etc. which would not routinely require admission.

Surgical and non-surgical conditions

We chose to try and distinguish between "surgical" and "non-surgical" conditions for the purpose of this study in order to determine the demographics of surgical disease in district and rural government hospitals as a proportion of the total hospital workload. However, an analysis of inpatient data from the United States showed that surgical care cuts across the entire spectrum of disease categories, with no disease subcategory always requiring an operation, and no disease category that never required an operation (Rose et al. 2014). If this holds true for low income countries as well, it would imply that hospitals still need to have the facilities and skills of a surgical care provider to offer a comprehensive package of care for any given medical condition.

Potential economic consequences

These two government district hospitals play a crucial role in averting death and disability from surgical disease in these countries. The economic impact of surgical disease is difficult to quantify and can be complicated to calculate but is likely to have a negative effect on average daily wage. According to the World Bank, the gross national income per capita for these countries is US $660 per annum for Sierra Leone and US $270 for Malawi (2013 figures) with life expectancy being 46 and 58 for men in these countries respectively. Untreated, a significant proportion of surgical disease results in death or disability. For example, a recent paper has suggested

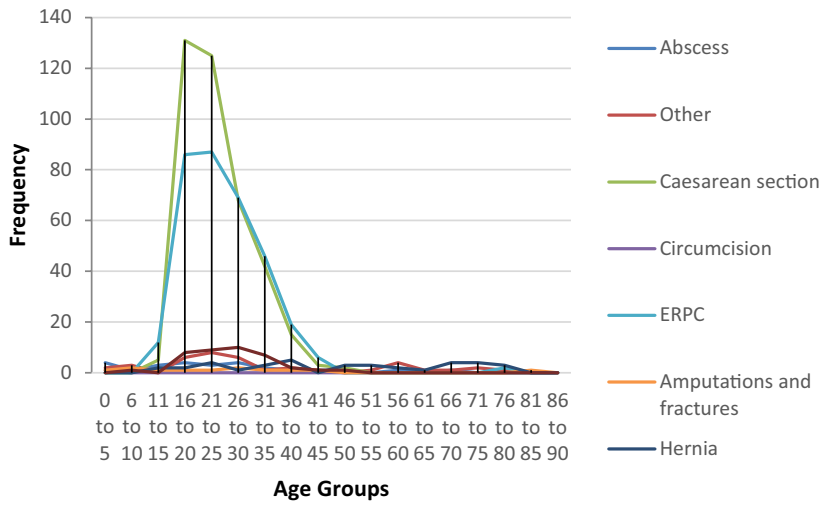

Fig. 7 Procedures performed at different age groups, Thyolo District Hospital, Malawi. Other: biopsy, bilateral tubal ligation, lump excision, suturing of vaginal tear, examination of rectum under anaesthetic, prostatectomy, scrotal exploration foreign body removal, vaginal stenosis procedure

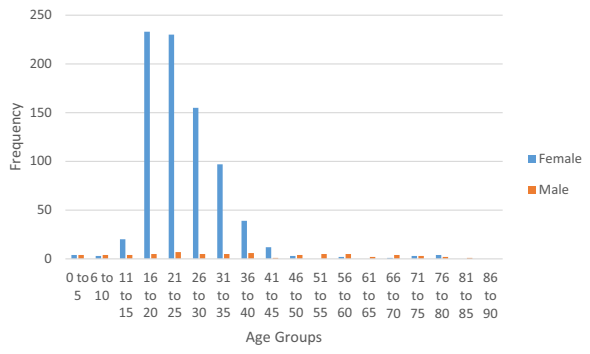

Fig. 8 Gender distribution for procedures at Thyolo District Hospital, Malawi

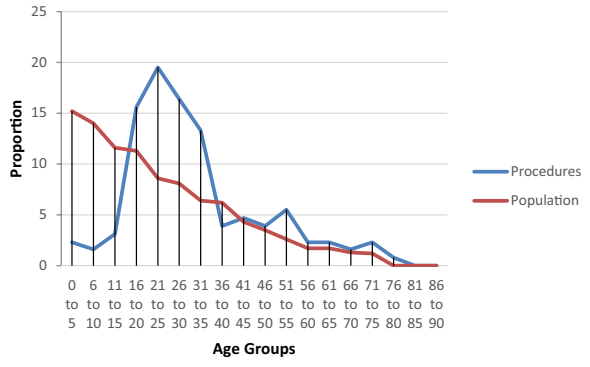

Fig. 9 Procedures performed compared with population demographic in Bo District

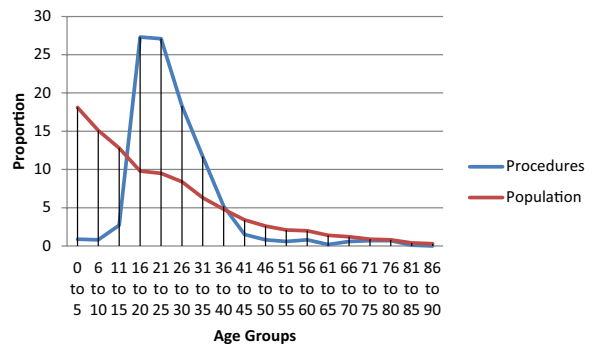

Fig. 10 Procedures performed compared with population demographic in Malawi

that if the rates of injury in low and middle income countries were reduced to those of high income countries, 2,117,500 lives could be saved each year with an economic saving of 758 and 786 billion dollars per year (Kotagal et al. 2014).

It has been shown that the health of a population impacts personal and national economic outcomes in several ways. Firstly, that healthy people are more likely to be employed and so there is a larger labour supply; secondly, that healthy people are likely to be more productive whilst at work; and thirdly, that healthy people are more likely to live longer, and in doing so, more likely to invest in their education (Thomson et al. 2009). Treating surgical disease, particularly as it predominantly

affects the under-35 year olds, and may have a positive impact on personal and national wealth.

For example, as the economies of both Malawi and Sierra Leone are partly agricultural, it would be anticipated that an inability to use a limb would reduce the income to any given household and result in loss of earnings, reduction of household income, impoverishment and potentially reduction in GDP. For example, agriculture is thought to account for approximately 58 % of GDP in Sierra Leone and 36.1 % GDP in Malawi (African Development Bank 2010). Furthermore, disability in such settings usually removes a second family member from productive labour because of the need to care for the one who is disabled.

There is some evidence to demonstrate this point. Danquah et al. have shown that cataract surgery reduces disability and improves the economy of the household as well as health-related quality of life, an effect which is sustained 6 years after surgery (Danquah et al. 2014). It would be expected that treatments to prevent death from, for example, bowel perforations, intestinal obstruction, ectopic pregnancy; or treatments to reduce disability from, for example, fractures would have similar long term economic impacts.

Unmet need and absconders

We estimated the met need to be 231 and 299 operations per 100,000 population per year in Sierra Leone and Malawi respectively. This is close to Weiser et al. estimate of 295 operations per 100,000 population per year (Weiser et al. 2008). In Sierra Leone, the total need has been estimated as 5200 operations per 100,000 per year (Hakon Bolkan, Capacare—unpublished) suggesting that the surgical need is only being met for 4 % of the Bo district population and this is likely to be similar for the Thyolo district population.

The estimation of unmet need in surgery (i.e. those who need treatment but do not obtain it) relies on population surveys of surgical conditions and verbal autopsy studies. A population based study of musculoskeletal impairment in Rwanda showed that the overall prevalence was 5.2 % of which 96 % required further treatment. 31.3 % were due to trauma and 3.8 % infection. 7.2 % were due to either the mal-union or non-union of fractures (Atijosan et al. 2008). A cross-sectional country wide survey in Sierra Leone suggested that 25 % of respondents reported a condition needing surgical attention and 25 % of deaths in the previous year may have been averted by timely surgical care (Groen et al. 2012).

The health system in Sierra Leone results in a number of patients being unable to afford the sometimes life-saving treatment that is required and an unknown number of patients abscond or fail to seek medical treatment as a result of this. Our study recorded only those that absconded after admission and therefore does not show the much greater unmet need of those who do not attend hospital in the first place.

Few other studies have addressed those who did not undertake surgical treatment because of costs. However, a study looking at elective surgery in rural Cameroon showed that of the 1213 patients presenting for preoperative evaluation, 544 did not return for the operation after being told the costs of their treatment, leading to an estimated potential loss of 2163 DALYs. The most significant factor associated with failure to return for care was high costs of preoperative payment (Ilbawi et al. 2013). Men were more likely to return than women.

It would be thought, therefore, that if the skills, facilities and funding were available to treat all general surgical, orthopaedic and maternal health conditions at these two different hospitals, free of charge, then the number of surgically related admissions and procedure rates would rise and related death and disability reduced, with a likely resulting impact on personal and national wealth.

This hypothesis is of particular importance in low income countries such as Sierra Leone and Malawi. Public district hospitals are in some cases the only accessible form of modern healthcare to many of the population. It is for this reason that the surgical services must not be centralised to the biggest towns, out of reach for the majority of the population. These services must be available in the district hospitals as part of a broader development strategy, keeping the young and the primary contributors to the household, and indeed the national economy, fit and healthy.

Authors' contributions

CEG: lead for the study—contributed to the concept, design, analysis of data, drafting of the work, final approval. MLB: substantial contribution to the analysis of the data and its interpretation, and revising of the manuscript. AJD: significant contribution to data collection from Sierra Leone and critical revision of the manuscript. ND: significant contribution to data collection from Malawi and critical revision of the manuscript. PMG: contributed to the collection of data, it's interpretation and context setting, with revision of the manuscript to place data in local context. TBK: contributed to the design of the study and context within Sierra Leone, interpretation of the data and manuscript revision—to place the data within its local context. NCM contributed to the design of the study and context within Sierra Leone, interpretation of the data and manuscript revision. AL: supervisor for the study, including concept, design and manuscript revision. CBDL: second supervisor for the study, including concept, design and manuscript revision. All are agreeable to be held accountable for the work. All authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

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Cost-effectiveness of Surgery in Low- and Middle-income Countries: A Systematic Review

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Abstract

Background There is increasing interest in provision of essential surgical care as part of public health policy in low- and middle-income countries (LMIC). Relatively simple interventions have been shown to prevent death and disability. We reviewed the published literature to examine the cost-effectiveness of simple surgical interventions which could be made available at any district hospital, and compared these to standard public health interventions.

Methods PubMed and EMBASE were searched using single and combinations of the search terms "disability adjusted life year" (DALY), "quality adjusted life year," "cost-effectiveness," and "surgery." Articles were included if they detailed the cost-effectiveness of a surgical intervention of relevance to a LMIC, which could be made available at any district hospital. Suitable articles with both cost and effectiveness data were identified and, where possible, data were extrapolated to enable comparison across studies.

Results Twenty-seven articles met our inclusion criteria, representing 64 LMIC over 16 years of study. Interventions that were found to be cost-effective included cataract surgery (cost/DALY averted range US$5.06–$106.00), elective inguinal hernia repair (cost/DALY averted range US$12.88–$78.18), male circumcision (cost/DALY averted range US$7.38–$319.29), emergency cesarean section (cost/DALY averted range US$18–$3,462.00), and cleft lip and palate repair (cost/DALY averted range US$15.44–$96.04). A small district hospital with basic surgical services was also found to be highly cost-effective (cost/DALY averted 1 US$0.93), as were larger hospitals offering emergency and trauma surgery (cost/DALY averted US$32.78–$223.00). This compares favorably with other standard public health interventions, such as oral rehydration therapy (US$1,062.00), vitamin A supplementation (US$6.00–$12.00), breast feeding promotion (US$930.00), and highly active anti-retroviral therapy for HIV (US$922.00).

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Conclusions Simple surgical interventions that are life-saving and disability-preventing should be considered as part of public health policy in LMIC. We recommend an investment in surgical care and its integration with other public health measures at the district hospital level, rather than investment in single disease strategies.

Introduction

Public health has traditionally been concerned with prevention of disease and promotion of health. Surgery has been regarded as primarily concerned with treatment once disease has occurred, rather than with prevention. Nevertheless, surgery is essential to the prevention of death and disability, as well as to the preservation of economic productivity, particularly where the incidence of obstetric complications is high, where important surgical pathology, such as trauma, is common, and where long-term disability or death is the outcome of such untreated pathology. Although surgery has long been described as the "neglected stepchild" of public health [1], in recent years there has been increasing interest in including surgical care as part of a comprehensive health strategy [2]. It has also been argued that access to essential surgical care is part of the basic human right to health [3].

It has been estimated that 11 % of the global burden of disease is due to injuries alone [4], and that figure is expected to be much higher if we include other surgical conditions. Between 1990 and 2010, there was a global shift from death and disability as a result of communicable diseases toward death and disability from non-communicable disease and injury [4]. Africa is estimated to have the highest proportion of disability adjusted life years (DALYs) due to surgical conditions at 38 per 1,000 population [2]. This figure includes injuries, malignancies, congenital anomalies, obstetric complications, cataracts and glaucoma, and perinatal conditions. This figure does not include other surgical pathology that may be important, such as infections, wounds, abscesses, septic arthritis, and osteomyelitis or hernias, because of a lack of available data, although there is evidence that some of these conditions may have high prevalence [5]. Wide disparities exist in global surgical care, with 34.8 % of the poorest third of the global population receiving only 3.5 % of all surgical procedures [6].

Despite the increasing awareness of the importance of strengthening surgical capacity globally, as reflected in such efforts as the 2008 Copenhagen Consensus [1, 7], basic surgical care is not a funding priority in many national policies [1]. However, policymakers face difficult decisions in assigning finite resources to various competing priorities, especially in health. Cost-effective analyses have become valuable tools in aiding decision makers to identify the most efficient ways of allocating resources for prevention, diagnosis, and treatment services for health [8]. Systematic reviews provide an excellent overview and an opportunity to compare various interventions. They are one of the tools used to enable policy makers make informed decisions on prioritization of funding where resources are limited [9, 10].

The recent inclusion of surgery as part of the World Bank's second edition of its Disease Control Priorities [2] heralded a turning point in the recognition of the importance of basic, essential surgical care. The chapter included an estimated cost-effective analysis of a community health center and a district hospital, with the assumption that information on a whole surgical service as an intervention would be of interest to policymakers. The dearth of published data was also highlighted.

Table 1 Priority 1 surgical conditions

Trauma
Surgical airway (threatened or obstructed airway)
Thoracostomy tube placement (hemothorax, pneumothorax
Exploratory laparotomy (hemoperitoneum, pneumoperitoneum, bowel injury)
Splenectomy, splenic repair, packing of hepatic injury, repair of small bowel perforation
Split-thickness skin grafting
External fixation
Toileting of open fracture
Closed management of most fractures
Pregnancy-related
Cesarean section
Management of ectopic pregnancy
Hysterectomy for postpartum bleeding and uterine rupture
D & C
Other surgical procedures
Hernia repair (umbilical, inguinal, femoral hernias)
Hydrocoelectomy
Appendectomy
Exploratory laparotomy (acute abdominal condition)
Bowel obstruction
Perforation
Cholecystectomy (acute cholecystitis)
Male circumcision
Incision and drainage (infection)
Drainage of septic arthritis
Repair of isolated cleft lip
Repair of club foot

Adapted from Mock et al. [11]

D & C dilatation and curettage

In 2010 Mock et al. [11] published a list of Priority 1 surgical conditions. These were those conditions that were thought likely to form a large public health burden, and that could be feasibly and successfully treated. We have summarized this list in Table 1.

In this article, we take the discussion on the cost-effectiveness of surgical interventions farther by reviewing existing published data on either single or integrated surgical interventions, synthesizing available information and highlighting areas of deficiency. We were also interested in looking at whether the proposed Priority 1 surgical conditions had data to support their cost-effectiveness or otherwise. To our knowledge, no systematic review has been done in this area. Therefore the present study may help guide future policies in the provision of basic surgical care as well as guide further research.

Methods

The databases of PubMed and EMBASE were searched from inception up to and including January 2013 using the single search terms and combinations of the search terms "DALY," "quality adjusted life year," "cost-effectiveness," and "surgery." Bibliographies and related citations in PubMed were used to identify additional articles. All titles and abstracts were reviewed. Where doubt existed, full texts were reviewed to determine suitability for inclusion.

Articles were included if they detailed the cost-effectiveness of a given surgical intervention of relevance to a low- and middle-income countries (LMIC) (World Bank classification 2011) using standard metrics such as DALYs, life years saved (LYS), or other applicable metrics used in cost-effectiveness analyses.

Articles were excluded if they were not in English, related only to high-income countries, or did not detail costs and related effectiveness. Only peer-reviewed studies were considered. Findings were reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guide.

Data comparison

To facilitate comparison between the studies, all cost estimates were converted to US dollars by using gross domestic product (GDP) deflators and then purchasing power parities (PPPs) [12]. Both GDPs and PPPs were obtained from the International Monetary Fund and the Organisation for Economic Co-operation and Development. The measure of effectiveness used was the DALY, a health metric that describes the morbidity and mortality due to a risk factor or disease in a population and is the standard unit used by the Global Burden of Disease Study [4]. It represents one healthy year of life lost due to early death or disability and is calculated by adding the years lived with disability and years of life lost. The effectiveness of a surgical intervention is measured as the number of DALYs the intervention averts. The cost-effectiveness is the cost for each DALY averted.

Cost per DALY averted was obtained by dividing the total cost of a procedure by the total number of DALYs that procedure averts [13]. However, in HIV treatment, effectiveness was defined as the number of HIV infections averted, calculated by projecting the reduction in HIV incidence over time [14]. In order to make meaningful comparisons across the different articles on male circumcision (in prevention of HIV transmission), we extrapolated the costs per HIV infection averted to costs per DALY averted, using a mean estimate of 15.50 DALYs per HIV infection averted (confidence interval 7.75–23.35 [15]).

Cost-effectiveness analyses have numerous methodologies. In an attempt to create guidelines to make results more comparable, the World Health Organization CHoosing Interventions that are Cost-Effective (WHO-CHOICE) project has created a standardized set of methods and tools used to analyze the societal costs and impacts of current and new interventions [16]. The WHO has suggested thresholds for determining whether an intervention is cost-effective based on work by the Commission on Macroeconomics and Health. An intervention that costs less than the GDP/capita per DALY averted is *very cost-effective*. An intervention that costs between one and three times the GDP/capita per DALY is still *cost-effective*, but an intervention that costs more than three times the GDP/capita per DALY is considered *not cost-effective*. We used the same parameters in this study to determine whether an intervention is cost-effective, as well as comparing the published cost per DALY averted figures for each condition.

Results

Figure 1 shows the search strategy using the PRISMA guide. Of 14,203 abstracts reviewed for suitability for inclusion in the initial search of the databases, a total of 36 full-text articles were accessed and reviewed further and their references scrutinized. Out of these, 27 met the inclusion criteria for qualitative synthesis. The included articles comprised different surgical interventions, with three articles on maternal and child health, one article on trachoma and trichiasis surgery, three articles on cataract surgery to prevent blindness, eight articles on male circumcision for HIV prevention, five articles on a whole hospital with basic surgical facilities, three articles on cleft lip and palate, two articles on hernia repair, and two

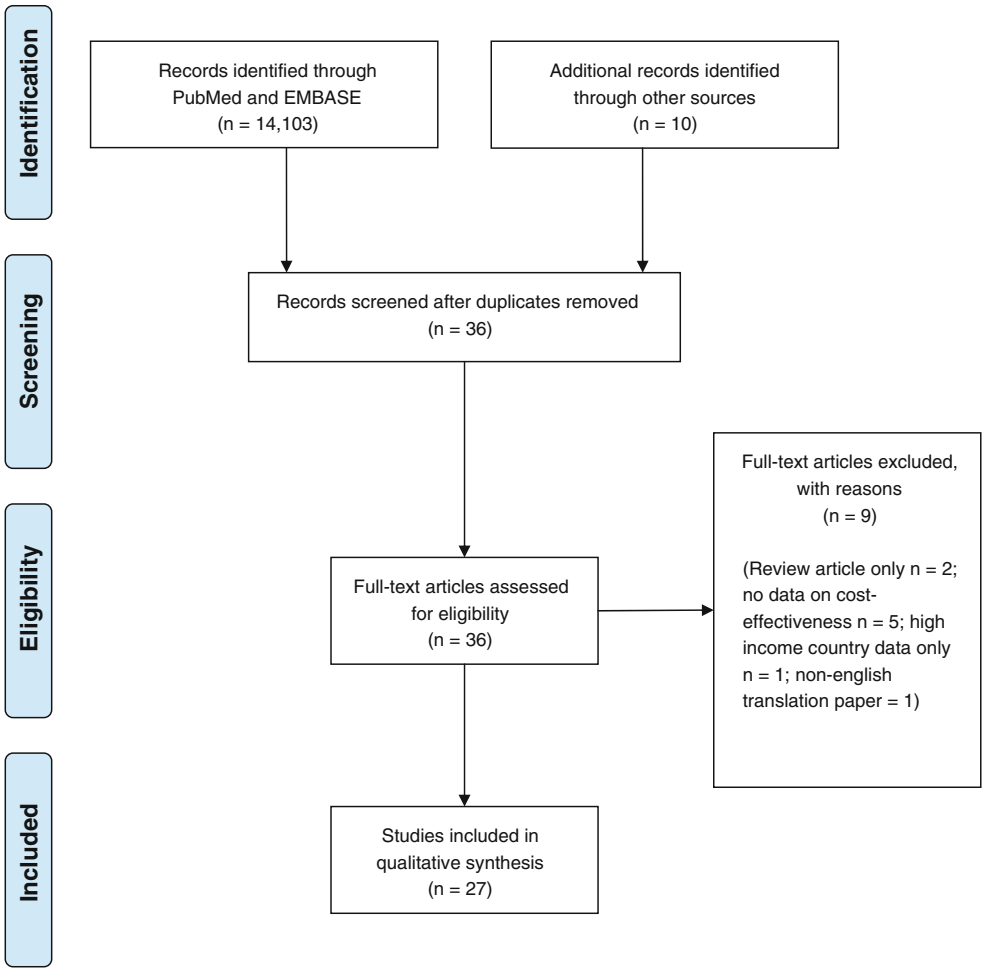

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram

articles on short-term orthopedic surgical missions. The articles represented 64 LMIC over 16 years of study.

The results are summarized in Table 2 [2, 5, 8, 13–15, 17–37]. Fourteen studies (51.9 %) use original data, while the rest used secondary data, hypothetical cohorts, or Global Burden of Disease (GBD) data. The methods used in quantifying cost-effectiveness were heterogeneous, with some articles describing the results of modeling based on estimates of disease incidence, prevalence, and costs. Other studies estimated the cost-effectiveness of whole hospitals or surgical missions, some comparing various health strategies for disease prevention and treatment for a number of different diseases within a single country, or direct cost-effectiveness estimates for single interventions on individual patients. Because of these differences, the studies were grouped according to interventions with individual assessments on cost-effectiveness.

Analysis of the three articles [13, 17, 18] assessing the surgical component of maternal and child health interventions, such as cesarean section for obstructed labor (OL), breech presentation, and fetal distress, showed that it is *very cost-effective* for 49 countries with low cesarean section rates except Zimbabwe, for which it is *cost-effective* [13]. Specifically, the researchers found the cost/DALY averted for cesarean section to be $376, with the GDP per capita being US$355 for 2008, US$492 for 2009, or US$591 for 2010, using World Bank estimates. One article found it only *cost-effective* for Southeast Asian regions (Sear-D), both on WHO Choice methods, and when we converted to GDP/capita per DALY averted [17]. The third article also found cesarean section to be *very cost-effective* for the Republic of Guinea [18].

One study modeled trachoma and trichiasis surgery, estimating the total cost-effectiveness at 80 % coverage to be I$71–$285 per DALY averted [8]. (I$ represents International dollars, a hypothetical unit of currency with the same purchasing power that the dollar has in the United States at a given time.) The three articles on cataract surgery [19–21] demonstrated it to be *very cost-effective* for treating blindness, with a study in Nepal reporting costs as low as US$5.06 per DALY averted. One study in India did a comparison between cataract surgery being offered at

Table 2 Cost-effectiveness studies

	Country/ region	Methodology	Data source	Intervention	Published cost-effectiveness	Metric	GDP/capita[a]	Cost-effectiveness[b]
Emergency obstetric surgery								
Adam et al. [17]	Afr-E Sear-D	Standardized WHO CHOICE methods	Effectiveness data from several sources, including trials, observational studies, and expert opinion	Cesarean delivery for OL, breech presentation, and fetal distress	ICER: I$73 (Afr-E) I$2,638 (Sear-D) ACER: I$28 (SSA) and I$38 (SEA)	Cost/DALY averted	Afr-E: I$1,576 Sear-D: I$1,449	Afr-E: Very cost-effective Sear-D: Cost-effective
Alkire et al. [13]	49 countries with insufficient cesarean deliveries to meet current demand	Economic and epidemiological modeling	World Bank, U.N., and global burden of disease (GBD) study	Cesarean delivery for OL	US$251–$3,462 (median: $304)	Cost/DALY averted	Variable	Very cost-effective for all except Zimbabwe, which is "cost-effective"
Jha et al. [18]	Guinea	Estimates of costs and effective ness for 40 interventions in Guinea	Original data	Cesarean delivery for OL Severe injury treatment Appendectomy Hernia repair	Cesarean delivery for OL: US$18 Severe injury treatment: US$278 Appendectomy:US$36 Hernia repair: US$74	Cost/LYS	US$ 467	Very cost-effective for all procedures
Eye surgery								
Baltussen and Smith [8]	Afr-E Sear-D	Literature review and mathematical modeling using standardized WHO CHOICE methods	Clinical and observational studies and population based surveys, published reports, expert opinion, and the WHO-CHOICE database.	Trachoma and trichiasis surgery (80 % coverage) ECCE (80 % coverage)	Afr-E: I$71 Sear-D: I$285 ECCE Afr-E: I$116 Sear-D: I$97	Cost/DALY averted	I$2,000	Very cost-effective
Baltussen et al. [19]	Afr-E Sear-D	Literature review using population modeling and costing estimates from global regions using standardized WHO CHOICE methods	Regional GBD data	ECCE (80 % coverage)	Afr-E: I$106 Sear-D: I$54	Cost/DALY averted	Afr-E: I$1576 Sear-D: I$1449	Very cost-effective ECCE favored over ICCE
Singh et al. [20]	Karnataka, India (Mysore)	Estimated costs divided by user satisfaction for survey of patients using standard methods	Original data	Cataract surgery (ICCE and ECCE)	Government camp: US$97 Medical college hospital (district hospital): US$176 NGO hospital: US$54	Cost/user satisfaction	US$ 352	Very cost-effective

Table 2 continued

	Country/ region	Methodology	Data source	Intervention	Published cost-effectiveness	Metric	GDP/capita[a]	Cost-effectiveness[b]
Marseille [21]	Lumbini zone, South Central Nepal	Cost-utility analysis of cataract surgery in a public health eye care program	Original data	Cataract surgery	US$5.06	Cost/DALY averted	US$204	Very cost-effective
Male circumcision								
Njeuhmeli et al. [22]	14 countries in SSA	DMPPT –Modeling tool that estimates epidemiologic impact and cost of scaling up	Original data, household surveys	VMMC	US$595.24 Overall cost (2011–2025): US$809 Zimbabwe: US$369 Rwanda: US$4,096 US$38.4[c]	Cost/HIV infection averted Cost/ DALY averted[c]	(2008) SSA US$1093.9	Very cost-effective
Uthman et al. [15]	SSA	Cost-utility analysis of AMC for the prevention of heterosexual acquisition of HIV Decision modeling of cost-benefit from government health care payer perspective	From three randomized trials and other sources	AMC	15 DALYs saved per HIV infection averted	DALYs saved/HIV infection averted	SSA US$1,093.9	Cost-effective Probability that AMC is cost-effective is 0.96
Bollinger et al. [14]	Botswana	DMPPT modeling tool that estimates epidemiologic impact and cost of scaling up	Recent estimates and simulations undertaken by the Botswana National AIDS Coordinating Agency	AMC	US$642 US$44.42[c]	Cost/HIV infection averted Cost/ DALY averted[c]	US$ 5425	Very cost-effective
Binagwaho et al. [23]	Rwanda	Cost-effectiveness model to determine cost per HIV infection averted	Three hypothetical cohorts in Rwanda: newborns, adolescents, and adult men	AMC	Infants: US$1,746.89 Adolescents: US$3,932 Adults: US$4,949 Adolescents: US$334 Adults: US$613 Infants: US$112.70[c] Adolescents: US$253.68[c] Adults: US$319.29[c]	Cost/HIV infection averted Cost/life year gained Cost/ DALY averted[c]	US$385	Very cost-effective at all levels
Auvert et al. [24]	14 countries in Afro E:	Modeling based on cost, demography and HIV epidemiology using WHO CHOICE standards	WHO CHOICE database	AMC	First 10 years: US$168 (133– 223) 20 years: US$338 (266–456) US$10.83–21.8[c]	Cost/HIV infection averted Cost/ DALY averted[c]	SSA US$1,093.9	Very cost-effective

Table 2 continued

	Country/region	Methodology	Data source	Intervention	Published cost-effectiveness	Metric	GDP/capita[a]	Cost-effectiveness[b]
Fieno [25]	Mozambique	Cost modeling	Original data	AMC	US$390 60 % coverage US$7.38	Cost/HIV infection averted Cost/DALY averted	US$368	Very cost-effective
Gray et al. [26]	Rakai, Uganda	Stochastic simulation modeling	Cohort study in Rakai	AMC	$1269–3911 75 % coverage, over 10 years US$81.87–$252.3[c]	Cost/HIV infection averted Cost/DALY averted[c]	US$393	Very cost-effective
Kahn et al. [27]	South Africa	Modeling based on estimates of incidence, prevalence and intervention costs	Hypothetical cohort of 1,000 newly circumcised South African adult men in the general population	AMC	25.6 % prevalence US$181 8.4 % prevalence US$ US$11.68-35.55[c]	Cost/HIV infection averted Cost/DALY averted[c]	US$5234	Very cost-effective
Hospitals with surgical services								
Gosselin et al. [28]	Nigeria Haiti	All costs and DALYs calculated for two surgical trauma hospitals using WHO CHOICE standards, DALY framework	Original data	Trauma hospital/emergency surgery	Nigeria: US$172 Haiti: US$223	Cost/DALY averted	Nigeria US$1,375 Haiti US$658	Very cost-effective for both countries
Gosselin and Heitto [29]	Cambodia	All costs and DALYs calculated for all hospital activities (trauma) over 3 months using WHO CHOICE standards, DALY framework	Original data	Trauma hospital/emergency surgery (trauma surgery)	US$77.4 per DALY averted	Cost/DALY averted	US$538	Very cost-effective
Debas et al. [2]	SSA	Cost estimates	Standardized regional figures, DALYs averted	District hospital with surgical services	US$33 (US$19–$102)	Cost/DALY gained	SSA US$1883.24	Very cost-effective
Gosselin et al. [30]	Sierra Leone	All costs and DALYs calculated for all hospital activities over 3 months for patients successfully treated for clearly life-threatening or disabling conditions	Original data	Entire hospital with surgical department	US$32.78	Cost/DALY averted	US$221	Very cost-effective

Table 2 continued

	Country/region	Methodology	Data source	Intervention	Published cost-effectiveness	Metric	GDP/capita[a]	Cost-effectiveness[b]
McCord and Chowdhury [31]	Bangladesh	All costs and DALYs calculated for all hospital activities over 3 months for patients successfully treated for clearly life threatening or disabling conditions ($n = 541$ patients)	Original data	Small rural hospital with basic surgical facilities	US$10.93	Cost/DALY averted	US$323	Very cost-effective
Cleft lip and palate								
Alkire et al. [32]	SSA	Economic modeling of cleft lip and cleft palate (CLP) using the DALY framework	Retrospective data	Cleft lip and palate	Both cleft lip and palate benefit to sub-Saharan Africa US$252 million–$441 million	Benefit VSL	SSA US$1,093.9	
Corlew [33]	Katmandu, Nepal	Economic modeling (GNI & VSL) using DALY framework ($n = 568$ patients) (Interplast)	Original data	Cleft lip ($n = 402$) Cleft palate ($n = 166$)	Average cost:US$29	Cost/DALY averted	US$298	Very cost-effective
Magee et al. [34]	Vietnam (5) Russia (1) Nicaragua (1) Kenya (1)	All costs and DALYs calculated for Operation Smile mission costs for eight missions ($n = 303$ patients) using the DALY framework	Original data	Volunteer short-term mission–cleft lip and cleft palate surgery	Vietnam: US$15.44 Russia: US$32.27 Nicaragua: US$66.01 Kenya: US$96.04 Average US$33.94	Cost/DALY averted	Vietnam US$1,070 Russia US$11,700 Nicaragua US$1,459 Kenya	Very cost-effective for all countries
Inguinal hernia								
Shillcutt et al. [35]	Northwestern Ecuador	All costs and DALYs calculated for two elective missions ($n = 102$ patients) using DALY framework, WHO-CHOICE standards	Original data	Voluntary short-term elective inguinal hernia repair using mosquito net/commercial mesh	US$78.18 (95 % CI 75.86–85.78) I$152.00 (95 % CI 145.91–172.55)	Cost/DALY averted	US$4,008	Very cost-effective
Shillcutt et al. [5]	West Ghana	All costs and DALYs calculated for one elective mission (4 regional hospitals in 5 days) using DALY framework, WHO-CHOICE standards	Original data, DALYs averted	Voluntary short-term elective inguinal hernia repair	US$12.88 (95 % CI 10.98–14.78)	Cost/DALY averted	US$1,090	Very cost-effective

Table 2 continued

	Country/ region	Methodology	Data source	Intervention	Published cost-effectiveness	Metric	GDP/capita[a]	Cost-effectiveness[b]
Short-term orthopedic missions								
Chen et al. [36]	Leon, Nicaragua	All costs and DALYs calculated for one elective surgical mission (n = 30 patients) using WHO CHOICE standards, DALY framework (DCP)	Original data	Short-term orthopedic surgical mission	US$352.15	Cost/DALY averted	GDP-US$1587	Very cost-effective
Gosselin et al. [37]	Nicaragua (2) Dominican Republic (1) Haiti (5)	All costs and DALYs calculated for three elective missions ($n = 117$ patients) vs five disaster relief missions ($n = 93$ patients) using WHO CHOICE standards, DALY framework	Original data	Short- term orthopedic surgical missions	Elective (Nicaragua, DR): US$362 Relief (Haiti): US$343	Cost/DALY averted	Nicaragua US$1456 Dominican Republic US$5195 Haiti US$664	Very cost-effective for all countries

OL obstructed labor; *ECCE* extracapsular cataract extraction; *VMMC* voluntary medical male circumcision; *AMC* adult male circumcision; *SSA* Sub-Saharan Africa; *Afr-D* countries in Sub-Saharan Africa with very high adult and high child mortality; *Sear-D* countries in Southeast Asia with high adult and high child mortality; *WHO CHOICE* World Health Organization Choosing Interventions that are Cost-effective; *DMPPT* Decision Makers Program Planning Tool; *ACER* average cost-effectiveness ratio; *ICER* incremental cost-effectiveness ratio; I$ International dollars—a hypothetical unit of currency with the same purchasing power that the dollar has in the United States at a given time; *DALY* disability adjusted life years; *LYS* life years saved; *Afr-E* Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe; *SEA* Southeast Asia; *ICCE* intra capsular cataract extraction; *VSL* value of a statistical life; *GNI* gross national income

[a] All GNI/GDP/capita figures from the World Bank at: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD, Accessed February, 2013

[b] WHO-CHOICE defines interventions that have an incremental cost- effectiveness ratio of less than the GDP per capita as very cost-effective, and those with a ratio less than three times the GDP per capita as cost-effective

[c] Cost/DALY averted calculated

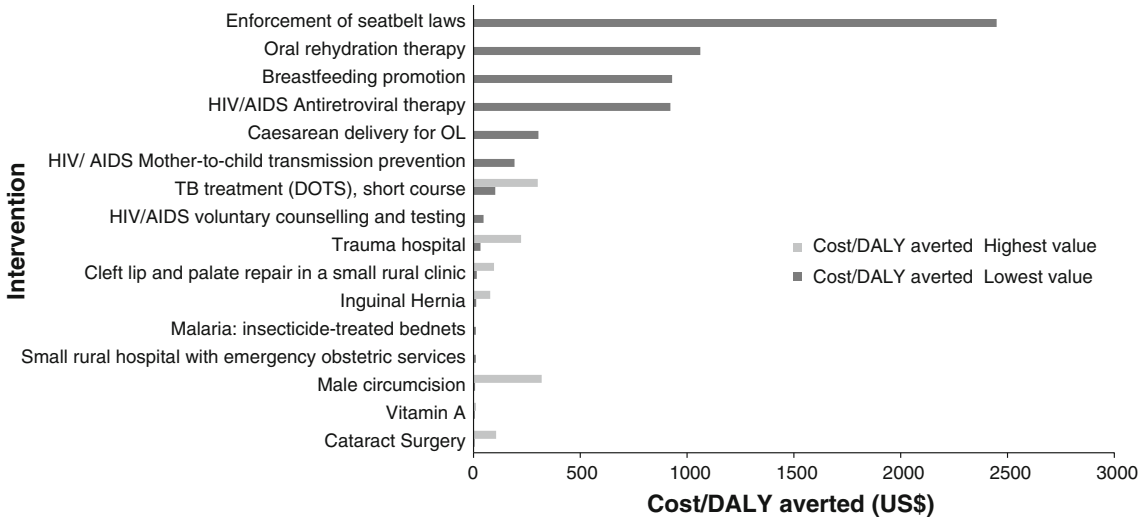

Fig. 2 Cost-effectiveness of surgical interventions compared with other public health interventions

different locations. They found the cost/user satisfaction score to be lowest at an NGO hospital and highest at a medical college hospital [20].

Analysis of the eight articles that examined the cost-effectiveness of male circumcision shows that the intervention is *very cost-effective* with a cost per DALY averted range of US$7.38–$319.29 [14, 15, 22–27]. Although one article stated that the intervention is highly cost-effective for infants and adolescents but is neither cost-saving nor highly cost-effective for adults [23], when we converted their figures to cost/DALY averted, at all levels, the intervention was *very cost-effective*.

Analysis of the five articles assessing the cost-effectiveness of a whole hospital providing surgical facilities showed that they were all *very cost-effective* [2, 28–31]. However, the hospitals varied with respect to their size and location, from a small 50 bed hospital in rural Bangladesh (cost/DALY averted US$10.93) [31] to larger trauma hospitals (cost/DALY averted US$ 32.78–$223) [28].

Articles on cleft lip and palate surgery showed treatment to be *very cost-effective*, ranging from US$15.44 per DALY averted for Vietnam to US$96.04 per DALY averted for Kenya [32–34].

Two articles on elective inguinal hernia repair showed this to be *very cost-effective* for two countries, Ghana and Ecuador, with a cost-effectiveness of US$12.88 and US$78.18 per DALY averted, respectively [5, 35].

Short-term orthopedic missions were also found to be *very cost-effective* when calculated by GDP/capita per DALY averted and US$343–$362 per DALY averted [36, 37]. We compared these surgical interventions to the cost-effectiveness of other accepted public health interventions as documented in the second edition of the World Bank's Disease Control Priorities for Developing Countries [38]. Figure 2 demonstrates this comparison and shows that these surgical interventions compare very favorably.

Discussion

In this article we have reviewed the cost-effectiveness of certain emergency and essential surgical procedures in LMIC using relevant studies and compared the results to accepted public health interventions. We attempted to create meaningful comparisons by judging the cost-effectiveness of the intervention based on standards set by the World Health Organisation. We have shown that majority of the surgical procedures reviewed in this article are *very cost-effective*, especially in poorly resourced settings. Unfortunately, for most of the proposed Priority 1 surgical conditions, there is little data regarding their cost-effectiveness.

There were five articles that did not address the cost-effectiveness of surgical procedures individually, but did look at the cost-effectiveness of hospitals with the ability to provide surgical care. This suggests that provision of care within the hospital context, not just as "camps" or "missions," is in itself cost-effective and therefore adds weight to the argument that integration of surgical care as part of a national health strategy may be cost-effective. Integration of care at the level of service delivery has been suggested to be vital to disease control programs [39], an ideal that is reflected in the fact that some of the major single disease interventions in global health are increasingly investing in integration of the intervention with general health systems [40].

There are limitations to this study. First, we attempted to homogenize the results to make them more comparable,

although the great variation in methodology is a significant limitation. This variation exists in part because there are two main reasons for undertaking a cost-effectiveness study. The first is to inform a specific decision maker, and thus the study is highly context specific. The second, is to provide general information about the relative cost-effectiveness of different interventions [41]. Both have strengths and weaknesses. For example, the articles looking at the cost-effectiveness of elective hernia repair used individual patient data and actual local costs, but are specific to the context in which they are studied [5, 35]. Therefore, extrapolating the results to different countries may not be valid. In the modeling articles, because of a lack of exact epidemiological numbers and local evidence, some authors have opted to use best estimates from a variety of sources to give estimates of cost-effectiveness from a global perspective [13]. It is difficult to be sure that these figures would apply in specific local contexts. Finally, some authors have estimated the cost-effectiveness of scaling up a single intervention within a geographical area [14, 24], which creates additional costs of building capacity, in addition to the provision of the intervention.

There is also a discrepancy as to whether and when discounting and age-weighting should be used. Although the original Global Burden of Disease Study used both, and the World Health Organisation guidelines recommend including levels of discounting [41]; the recent Global Burden of Disease analysis uses neither [4]. Similarly, we found that some of the articles included in our analysis used discounting and added age-weighting in the sensitivity analysis, whereas others did not. This adds another level of complexity when trying to make meaningful comparisons.

Nevertheless, we assessed each individual article against the standard set by the WHO in terms of assessing the cost-effectiveness of interventions. Where the metric used in assessing effectiveness (e.g., DALYs averted vs life-years saved) was completely different, no attempt was made to extrapolate the results.

Another limitation to the present study is the sparse number of studies on a particular intervention (e.g., inguinal hernia repair, cesarean section for OL), which limits the scope of the discussion. Some of the articles were quite context-specific, which means that it is difficult to determine how generalizable their results are.

It is worth noting that the surgical interventions presented here were based on published data and are not representative of the majority of simple, low-cost, life-saving and disability-preventing procedures that could be of tremendous medical and economic benefit to a country, as listed in the priority 1 surgical conditions (Table 1). These procedures include clubfoot manipulation and casting, incision and drainage of abscesses, reduction of fractures and dislocations, wound debridement, intercostal drainage, suprapubic catheterization, amputation, emergency exploratory laparotomy, cranial burr holes, and tracheostomy/cricothyroidotomy. To date, there are no studies documenting the cost-effectiveness of these interventions, and yet it is just these interventions that may prove to be the most cost-effective.

We recommend that further studies be carried out to assess the impact on death and disability rendered by simple surgical procedures in low resource settings. We have shown that cesarean section for OL, adult male circumcision for HIV prevention, cataract surgery for blindness, cleft lip and palate repair, and an integrated surgical unit in a district hospital are highly cost-effective interventions and compare favorably with other general preventive health interventions. Policymakers and researchers should focus more on widespread provision of priority surgical interventions as part of an integrated public health strategy.

Conflict of interest None.

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The cost-effectiveness of orthopaedic clinical officers in Malawi

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Abstract

Background: In Malawi the orthopaedic clinical officer (OCO) training programme trains non-physician clinicians in musculoskeletal care. We studied the cost-effectiveness of this program.

Methods: Hospital logbooks were reviewed for data pertaining to activity in seven district hospitals over a 6-month period. The total costs were divided by the total effectiveness, calculated as disability adjusted life years (DALYs) averted.

Results: The total cost-effectiveness of providing orthopaedic care through the OCO training programme was US$92.06 per DALY averted. The mean per hospital was US$138.75 (95% CI: US$69.58–207.91) per DALY averted which is very cost-effective when compared with other health interventions. Of the 837 patients treated 63% were aged <15 years and 36% were in the 'economically active' demographic of ages 15–74 years.

Conclusion: Training of clinical officers in orthopaedic surgery is very cost-effective and allows transfer of skills into rural areas. The demographics suggest that failure to provide such care would have a negative economic impact.

Keywords

Orthopaedic clinical officers, Cost-effectiveness, Task shifting

Introduction

Sub-Saharan Africa has 25% of the global burden of disease and only 3% of the global healthcare work force[1] and therefore has developed different solutions, compared to high income countries, to the care of sick and injured individuals. The term 'task shifting' has been used to describe the transfer of tasks traditionally done by physicians to non-physician clinicians (NPCs) or healthcare workers with paramedical training. The clinical outcomes as a result of such healthcare providers performing surgery have been shown to be no different compared to when the care is provided by a formally trained doctor.[2] For example, a study in Ethiopia demonstrated that even though NPCs performed 55.5% of all Caesarean sections, maternal or fetal death and length of hospital stay were not significantly different from those patients who had the surgery performed by a hospital doctor.[3] Furthermore, Wilson *et al.*'s meta-analysis of controlled studies found no difference in outcomes following Caesarean sections performed by doctors compared with NPCs.[4] The World Health Organization (WHO) now recommends that such task shifting be used to improve access to maternal health interventions.[5] Similar results have been demonstrated for other examples of task shifting in both surgical and anaesthetic care.[6,7]

Malawi has 26 government district hospitals and four central (referral) hospitals. The majority of the clinical work done in these district hospitals is performed by clinical officers, a form of NPC. In Malawi, there are a number of different NPCs. Medical assistants are the least senior band of health

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worker who can diagnose and prescribe. They undertake 2 years of training following their schooling followed by a 1-year internship. Medical assistants predominantly work in the health centres but some work at district hospital level. The clinical officer level is higher. They undertake 3 years of training followed by a 1-year internship. Academic requirements for clinical officers are also higher than those for medical assistants, with an emphasis on the sciences. Orthopaedic clinical officers (OCO) are general clinical officers who undergo further training in the form of an 18-month diploma. Regulated by the Medical Council of Malawi, they are subspecialists who primarily perform orthopaedic procedures, although also perform general clinical work as needed.

OCOs have been trained since 1985 and manage 80–90% of orthopaedic conditions in the district hospitals. They are educated in the management of common traumatic and non-traumatic conditions.[8] The OCO program is designed to keep the provider in the local district so as to attend to orthopaedic problems locally. This allows for greater access for the majority rural population and prevents overloading the central hospitals. Mkandawire *et al*. showed that these workers cost $7,253 to train over an 18-month period versus $52,000 over 9 years to locally train a competent orthopaedic surgeon,[8], although the cost of training a consultant surgeon is likely to be significantly underestimated as the tuition fees are highly subsidised by the government. Although the central hospitals often have several OCOs working alongside fully trained orthopaedic surgeons, our aim was to look at the cost-effectiveness of OCOs in the district hospitals.

Methods

Setting

Malawi can be divided into the northern, central, and southern regions. All of the district hospitals are rural. Each district hospital has within its catchment area approximately 20 smaller health centres, which themselves are staffed by medical assistants (who are also NPCs) who are not specialty trained, nurses, a health surveillance assistant, and have a standard drug list, a functional communication system, running water and access to transport by bicycle ambulance, motorcycle ambulance or a motor vehicle.

Each district hospital has 130–350 beds and up to 15 clinical officers who rotate between surgery, obstetrics, internal medicine and paediatrics. Each hospital has a male, female, paediatric and obstetric ward. All have delivery suites and a major operating theatre along with one or two minor theatres. Each hospital has one or two OCOs with one or two medical assistants who work with them. There are no functioning post-anaesthesia units or recovery rooms and therefore most patients are admitted to and recover on the ward.

Sampling

We took a convenience sample of seven district hospitals spread throughout the three regions based on the practicality of travel though the entire country over a 3-week period and the quality of the logbooks in these hospitals. Figure 1 shows the position of the hospitals within Malawi and Table 1 shows the staffing levels.

We studied two 3-month intervals in order to duplicate the models used in previous studies.[9,10] We chose 3 months in the rainy season (December to February) and 3 months in the dry season (April to June) to see

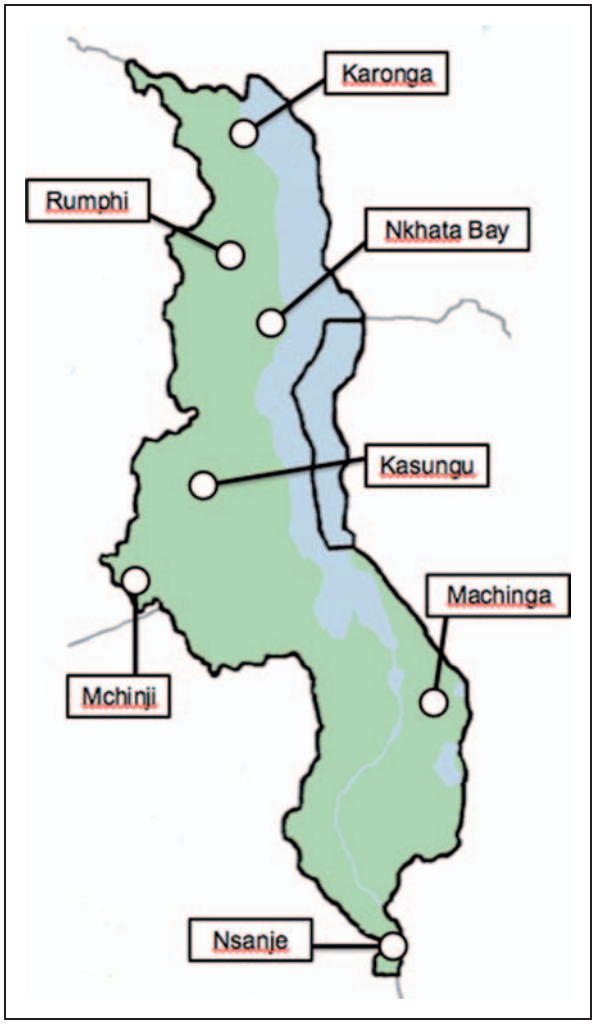

Figure 1. Map of Malawi showing position of the hospitals in this study.

Table 1. Staffing levels at the district hospitals.

Name of hospital	Beds (*n*)	OCOs (*n*)	General COs (*n*)	Medical assistants (*n*)	Nurses (*n*)	Admin staff (*n*)	Doctors (*n*)
Nsanje District Hospital	300	1	8	22	65	242	2
Machinga District Hospital	257	3	14	5	75	118	1
Mchinji District Hospital	209	2	15	9	52	9	2
Kasungu District Hospital	219	3	20	36	86	163	3
Nkhata Bay District Hospital	137	2	11	17	60	9	2
Rumphi District Hospital	243	1	18	8	35	58	1
Karonga District Hospital	208	1	12	4	56	7	1

if there was a difference in injury pattern with the seasons.

We attempted to identify all patients who had a manipulation, anaesthetic or both for an orthopaedic condition. This was achieved by analysis of theatre, outpatient and ward logbooks. Although some conditions are treated on an outpatient basis, the majority of those who had an anaesthetic stayed in hospital overnight, either before or after the procedure. Because of this any patient missing from the one logbook (e.g. theatres) could be found in another (e.g. ward). In this way we planned to identify the majority (approximately 90%) of patients treated by the OCOs.

Estimation of costs

Set-up costs

Mkandawire *et al.* estimated the cost of training an orthopaedic clinical officer over 18 months to be US$7,253.[8] This cost includes the salaries of two OCO instructors, books for all the students, and a basket of orthopaedic tools to take to the first hospital they are assigned to.

We estimated the current cost of each OCO stipend to be $1,200 based on 330,000 Kwacha (K) given for food and lodging for 18 months for each OCO student and using July–August 2012 exchange rates of US$1.00 = K275.

Ongoing costs

We used an average salary of each OCO once trained as being US$939.99 for a 6-month period. This was based on the salary of a junior OCO of 36,539 K a month and a senior OCO salary of 49,619 K per month. Estimated salaries of the medical assistants were based on 60% of an OCO salary, which is US$536.99 for 6 months.

Only the cost of treating patients who needed a manipulation or operation were included under the assumption that other patients could have been treated by medical assistants or general clinical officers alone.

We obtained local costs of equipment for use in common operations, principally costs of Plaster of Paris for fracture manipulations and average costs of ketamine anaesthesia used per patient from local hospital pharmacy stores. We estimated the costs of hospital stay per day, using cost estimates from the WHO CHOICE website, which for an inpatient stay for a primary level hospital in 2008 were US$1.66.[11]

We estimated a 70-day hospital stay for a hip or femur fracture requiring traction, 1 day for a manipulation under anaesthetic, 6 days following an amputation, and 1 day for a supra-condylar fracture. Cost of plaster and cotton were estimated to be 350 K or $1.27 per bandage. We estimated three rolls of plaster and cotton bandages per patient. We calculated an anaesthetic dose of 1.0 mg/kg with an average cost of just over US$1 per patient. Cost of X-rays were calculated to be US$18.18 per X-ray with an estimated two X-rays required for each case (pre and post reduction of fractures), except amputations. Costs per procedure are shown in Table 2. Drainage of abscesses was included in the calculations following informal discussion with healthcare and hospital staff, as well as observation of the research team, which showed that the majority of abscesses were drained by OCOs rather than the general clinical officers of medical assistants.

Estimating effectiveness

We used the same method used by McCord and then modified by Gosselin to estimate the disability adjusted life year (DALY) averted per patient.[9] The DALY is a way of measuring cost-effectiveness for global interventions and is used both by the Global Burden of Disease study and by the World Bank's Disease Control Priorities for Developing Countries.[12,13] It consists of estimates of the years of life lost through death (YLL) added to the estimated years of life lived with disability (YLD) such that DALY = YLL + YLD for a given

Table 2. Costs for procedures.

Procedure	X-rays (*n*)	Cost of x-rays (US$)	Plaster/ cotton bandages (*n*)	Cost per plaster/ bandage (US$)	Anaesthetic (*n*)	Cost per anaesthetic (US$)	Days hospital stay (*n*)	Cost per day (US$)	Total cost
Cost per hip fracture or femur fracture in traction	1	18.18	0	1.27	0	1.5	70	1.66	134.38
Cost per manipulation under anaesthetic	2	18.18	3	1.27	1	1.5	1	1.66	43.33
Cost per amputation	0	18.18	0	1.27	1	1.5	6	1.66	11.46
Cost per supracondylar fracture	2	18.18	3	1.27	1	1.5	1	1.66	43.33

Table 3. Weights for disease severity and effectiveness of treatment.

	Weight
Severity of disease	
Disease considered fatal >95% of the time	1.0
Conditions fatal >50% of time but <95% of time	0.7
Conditions fatal >5% of time but <50% of time	0.3
Conditions fatal <5% of time	0.0
Effectiveness of treatment	
>95% chance of permanent cure	1.0
<95% chance but >50% chance of permanent cure	0.7
<50% chance but >5% chance of permanent cure	0.3
<5% chance of permanent cure	0.0

From Gosselin *et al. World J Surg* 2006; 30: 505–511.

cause of illness. We used the most recent estimates of life expectancy from the Global Burden of Disease Study[14] and the most recent disability weights.[15] We gave additional weights for disease severity and effectiveness of treatment (Table 3) in line with previous studies.[9] For example, a 65-year-old with a forearm fracture which is treated (disability weight of 0.050 as for fracture of radius or ulna; condition fatal <50% of the time; >50% chance of permanent cure $= 23.29 \times 0.050 \times 0.3 \times 0.7 = 0.245$ DALYs averted). The total costs and total DALYs were calculated, as well as the total cost and total DALYs averted per hospital.

We used the suggested thresholds for determining whether orthopaedic intervention is cost-effective based on the WHO Commission on Macroeconomics and Health. An intervention that costs less than the GDP/capita per DALY averted is deemed very cost-effective and an intervention that costs between one and three times the GDP/capita per DALY is still cost-–effective. An intervention that costs more than three times the GDP/capita per DALY is considered not cost-effective.[16] While conducting this research Malawian GDP/capita was US$268.05.

Results

Patient population

In the seven hospitals, a total of 837 patients were treated for orthopaedic injuries, which ranged from 82–282 per district hospital. Of these 68.1% were male patients and the mean age was 20. One hundred and fifty-four patients (15%) were aged 0–5 years, 484 (48%) were aged 6–15 years, 360 (36%) were aged 16–74 years, and seven (<1%) were aged ≥75 years. Thus >99% were either within the economically active demographic or would enter it in due course. The overall range in age was from 2 months for club foot treatment to 80 years for hip fractures. In the rainy season of December to February there were more crocodile bites to fishermen and slightly more (56%) forearm and supracondylar elbow fractures to children climbing mango trees. In the 6 months studied, 9% of all injuries were to the forearm with another 14% being supracondylar elbow fracture. The most common diagnoses (abscess drainage, ankle fracture/dislocation, osteomyelitis, supracondylar elbow fracture, tibial fracture and radial or ulnar fracture) were analysed in order to illustrate age distribution for these conditions (Figure 2).

DALYs averted

Overall, the total costs divided by the total DALYs gave a cost-effectiveness of US$92.06 per DALY averted. The breakdown for the cost/DALY averted for each hospital is shown in Table 4. The cost-effectiveness varied from hospital to hospital with the most cost-effective ones being those that performed the most operations (e.g. US$26.26 per DALY averted for Rumphi). The mean cost/DALY averted, i.e. the mean of the total costs for each hospital divided by the total DALYs averted for each hospital, for the

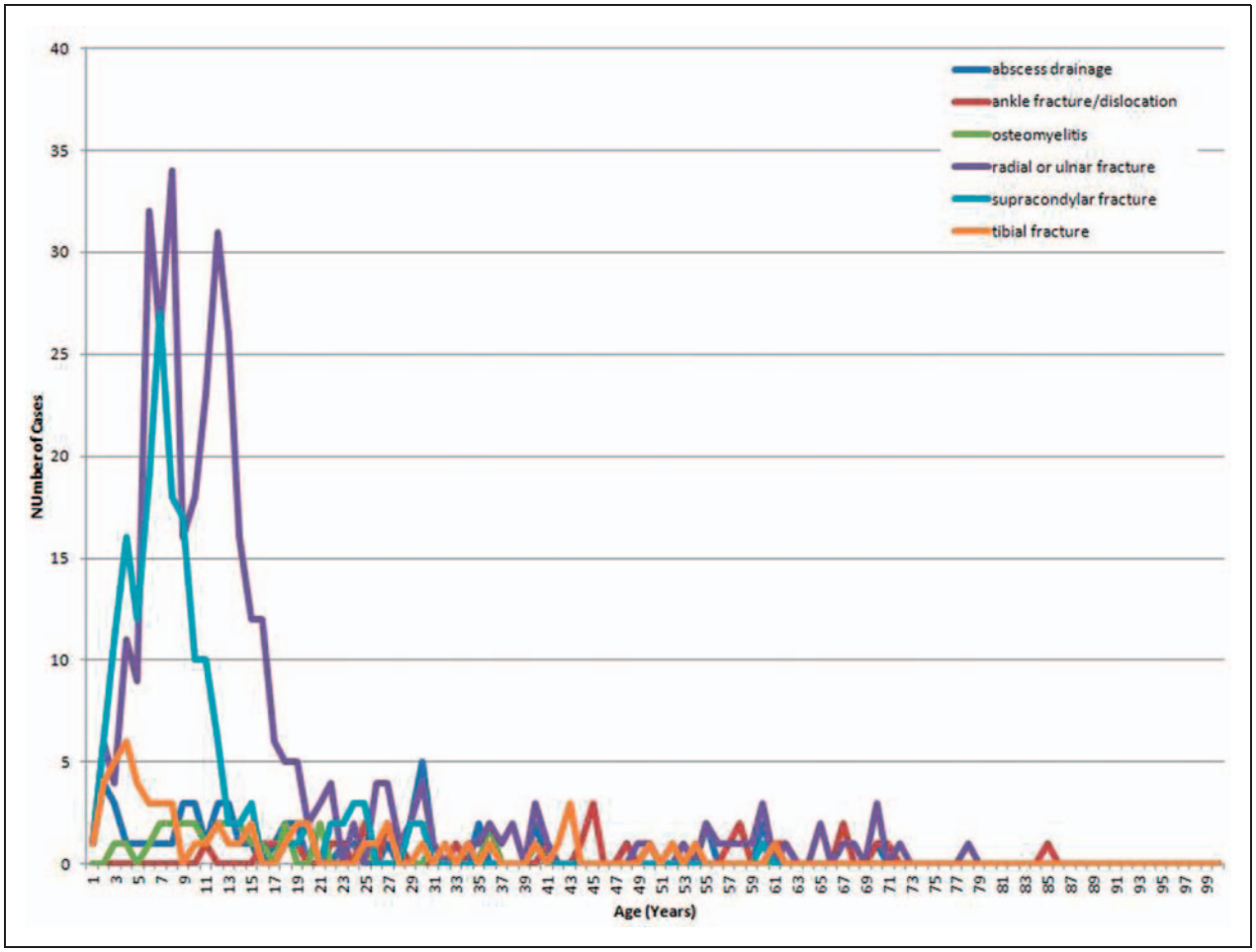

Figure 2. Graph showing ages and frequency per diagnosis.

orthopaedic clinical officer programme was US$138.75 per DALY averted with a 95% confidence interval of US$69.58–207.91 per DALY averted. This study found that the intervention cost less than the GDP/capita per DALY averted and, as such, can be considered very cost-effective.

Discussion

Our study suggests that orthopaedic clinical officers are very cost-effective for the provision of essential and emergency orthopaedic care in rural areas. This result is consistent with a previous study (2013) which showed that the majority of surgical procedures in low and middle income countries (LMICs) are very cost-effective and compare favourably with accepted public health interventions.[17] Specifically, orthopaedic clinical officers may be more cost-effective than oral rehydration solution for diarrhoea (US$132 per DALY averted), and are more cost-effective than anti-retroviral therapy for HIV (US$350–500 per DALY averted), and breast feeding promotion (US$930 per DALY averted).[18] Furthermore, the figure of US$138.75 per DALY averted compares favourably with short-term orthopaedic missions which have also been found to be very cost-effective at US$343–362 per DALY averted.[19,20]

The degree of cost-effectiveness varied from one hospital to another with the volume of operations. One potential reason for this is the variation in supply chain and facilities between the hospitals. Alternatively, it might be that more patients presented to some hospitals than others. The methodology of this study was not designed to investigate such factors.

The cost-effectiveness of orthopaedic task-shifting is not well studied but has been demonstrated in other areas of medicine.[21] Although our results show that the OCO programme is very cost-effective, initial observations suggested it to be more cost-effective than our results propose. Orthopaedic interventions tend to avert disability, rather than death, and therefore they do not avert as many DALYs when compared to life-saving surgery.

Figure 2 shows that, for the most frequently occurring diagnoses aside from ankle fracture/dislocation,

Table 4. Costs and DALYs averted by hospital.

Hospital	OCOs (*n*)	Medical assistants (*n*)	Total personnel cost	Fracture hip/femur in traction (*n*)	MUAs (*n*)	Amputations (*n*)	Supracondylar fractures (*n*)	Total procedures (*n*)	Total procedure costs (US$)	Total costs (US$)	Total DALYs averted	Cost/DALY averted (US$)
Nsanje	1	1	99,29.98	1	109	19	23	152	6,071.68	16,001.66	102.45	156.18
Machinga	1	2	10,466.97	8	156	3	33	200	9,298.79	19,765.76	174.33	113.38
Mchinji	2	2	19,859.96	1	282	3	48	334	1,4467.66	34,327.62	358.72	95.69
Kasungu	2	2	19,859.96	4	226	0	34	264	1,1803.32	31,663.28	271.57	116.59
Nkhata Bay	2	1	19,322.97	0	82	1	4	87	3,737.84	23,060.81	70.02	329.36
Rumphi	1	2	10,466.97	17	89	2	15	123	6,813.70	17,280.67	658.01	26.26
Karonga	2	1	19,322.97	12	119	0	22	153	7,722.09	27,045.06	202.18	133.77
Total for six months			10,9229.78	43	1,063	28	179	1313	59,915.08	16,9144.86	1,837.28	92.06

MUA, Manipulation under anaesthetic.

the majority of diseases requiring orthopaedic intervention occur in the 1–15-year age groups. This contrasts data from the Centers for Disease Control National Ambulatory Medical Care Surgery which found that those aged less than 15 years accounted for 5% of all patients, the smallest of all analysed age groups.[22] This highlights that, in Malawi, those aged 1–15 years are particularly vulnerable to surgical disease requiring orthopaedic intervention including abscess drainage, osteomyelitis, supracondylar fracture, tibial fracture and radial or ulnar fracture. Enabling access to such surgical care during these formative years may ensure that they are able to be fully economically active in later years, resulting in a long-term benefit to the economy.

There are limitations to our study. Primarily, this was a convenience study of district hospitals. There may also be an inherent selection bias present, in that those district hospitals that are easiest to get to may provide better or more effective care than those in more remote locations. Secondly, the data were frequently incomplete. We attempted to resolve this issue by searching other logbooks and estimate that we captured 85–90% of the data.

Our study was unable to account for all of the costs of the OCO programme. It was not possible to calculate the set-up costs and the equipment used exclusively by the OCOs. Other costs which were shared (e.g. sterilisation equipment, nursing staff, bed linen, etc.) are not included. In addition, although we included direct training costs, salaries and equipment costs per procedure, we did not include or examine the costs to the patient, or the indirect costs incurred by either patient or provider. Although care is free to the patient at the point of delivery in Malawi, there remain direct costs related to transport to and from the hospital, and indirect costs related to loss of income. By provision of care in local hospitals, these costs are likely to be significantly reduced.

Despite the limitations, our study suggests that training of NPCs in essential and emergency orthopaedic procedures in district hospitals in low income countries is a cost-effective way of providing care to the rural populations and prevents significant and unnecessary disability. Further cost-effectiveness may occur from returning individuals to a state whereby they can continue to earn income.

Declaration of conflicting interests

None declared.

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ORIGINAL SCIENTIFIC REPORT

Cost-Effectiveness of Two Government District Hospitals in Sub-Saharan Africa

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Abstract

Background District hospitals in sub-Saharan Africa are in need of investment if countries are going to progress towards universal health coverage, and meet the sustainable development goals and the Lancet Commission on Global Surgery time-bound targets for 2030. Previous studies have suggested that government hospitals are likely to be highly cost-effective and therefore worthy of investment.

Methods A retrospective analysis of the inpatient logbooks for two government district hospitals in two sub-Saharan African hospitals was performed. Data were extracted and DALYs were calculated based on the diagnosis and procedures undertaken. Estimated costs were obtained based on the patient receiving ideal treatment for their condition rather than actual treatment received.

Results Total cost per DALY averted was 26 (range 17–66) for Thyolo District Hospital in Malawi and 363 (range 187–881) for Bo District Hospital in Sierra Leone.

Conclusion This is the first published paper to support the hypothesis that government district hospitals are very cost-effective. The results are within the same range of the US$32.78–223 per DALY averted published for non-governmental hospitals.

Introduction

We have previously argued for investment in district hospitals in low-income countries, as key to the development of sustainable, long-term healthcare solutions [1]. District hospitals need investment as part of health system strengthening and the need to progress towards universal health coverage (UHC) [2] as well as to achieve the sustainable development goals (SDGs) [3].

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District hospitals are also key to strengthening surgical care, or universal coverage of essential surgery (UCES) [4]. Provision of essential surgical procedures, largely at district hospitals, could avert an estimated 1.5 million deaths per year, or 6–7% of all avertable deaths in low- and middle-income countries (LMICs) [4]. The Lancet Commission on Global Surgery (LCoGS) highlighted the huge burden of untreated conditions requiring surgical care, with mortality rates from lack of surgical access significantly exceeding mortality rates from key infectious diseases [5]. Surgery is required by all areas of medicine—a proportion of patients in every Global Burden of Disease (GBD) category required a procedure in an operating room [6]. One LCoGS target is that 80% of the global population should have access within 2 h to a facility that can perform the Bellwether Procedures (emergency caesarean section, laparotomy or open fracture fixation). This ambitious target will require significant investment in district hospital care. Anecdotal evidence suggests that improvement in surgical district hospital care would have a general effect on health by acting as an "enabler," to raise the overall quality of health care and encouraging patients to seek care for non-surgical conditions [7].

However, district hospital provision is in crisis, particularly in Africa, both in terms of the number needed per population [2], and the quality and presence of key basic medical and surgical facilities [8–10]. If we are to meet global health targets, as well as the global surgical targets, there will be a need for massive investment in district hospitals, both in the number of them and their ability to provide quality health care.

Cost-effectiveness studies to date have not assessed the cost-effectiveness of government district hospitals although they are thought to probably be highly cost-effective [4]. To date, four studies have been performed, most from the perspective of the district hospital as a surgical platform [11–14], but all of which were in non-governmental sector hospitals, and three of the studies included hospitals that did not provide obstetric care. Overall, the cost-effectiveness for non-governmental trauma hospitals was US$32.78–223 per disability-adjusted life year (DALY) averted. The exclusion of obstetric care may be crucial as obstetric care was shown to be the source of the highest number of averted DALYs in the McCord study in rural Bangladesh [11]. Debas et al. [15] estimated that the ideal first-level referral hospital as a platform for surgical care provision should be highly cost-effective at an estimated US$33 per DALY averted for sub-Saharan Africa. Our aim was to determine the cost-effectiveness of an entire government district hospital in sub-Saharan Africa.

Methods

Setting and data collation

We chose two busy rural government district hospitals in two different countries of sub-Saharan Africa—Sierra Leone and Malawi. The hospitals were chosen because they were felt to maintain good records and were similar in size and capacity. The characteristics of these two hospitals are shown in Table 1. We estimate that we captured data from at least 90% of all admissions.

Thyolo District Hospital, Malawi

Malawi is a landlocked country in East Africa and has a population of approximately 15 million of which 85% live in rural areas. Thyolo District Hospital in southern Malawi is a 350-bed government district hospital catering for a population of approximately 600,000. It has one fully qualified doctor, the District Medical Officer, who has the responsibility for the overall running of the hospital with the majority of the clinical work being performed by 20 paramedics (clinical officers) supported by nursing staff. It has two operating theatres, but only one that was in regular use during the period covered by this study. In Malawi, medical and surgical treatment is free at the point of delivery and patients therefore do not have to pay for equipment, patient stay, or any costs associated with their care including the operative procedure.

Bo District Hospital, Sierra Leone

Sierra Leone in West Africa has a population of approximately 6 million with 60% of the population living in rural areas. Bo District Hospital in Sierra Leone is a 450-bed government district hospital catering for a population of

Table 1 Hospital characteristics 2012

	Thyolo DH, Malawi	Bo DH, Sierra Leone
Population catchment	600,000 approx	600,000 approx
Number of beds	350	450
Staffing		
Doctors	3	1
Medical officers	0	4
Clinical officers	31	n/a
Nursing staff	116	229
Allied medical staff	40	94
Administration staff	20	10
Other (cleaners, drivers, etc.)	300	49

approximately 600,000. It has two operating theatres, but at the time of data collection, only one was in use.

In Sierra Leone, although health care is free at the point of delivery for under 5's, pregnant and lactating women, all other patients have to pay for costs related to bed stay, equipment, supplies, medications, investigations and the operation. The costs of the operation are divided into minor, intermediate and major procedures and are set centrally by the government each year.

Data collection

Whole hospital inpatient data were collected retrospectively from two separate 3-month periods, representing rainy and dry seasons, through rigorous review and analysis of logbooks from all wards and theatres. The different sets of data were cross-referenced and duplicates removed.

In Sierra Leone, all hospital data were collected for the months of July to September 2012 inclusive and February to April 2013 inclusive to capture both rainy and dry seasons. In Malawi, all hospital data were collected for the months of January to March 2013 and April to July 2013.

DALY calculation

For each diagnosis, we used a weighting system used by previous authors [11–13, 16, 17] to determine the likely threat to life without treatment, the likelihood of permanent disability and the likely efficacy of treatment (Table 2). Weights for each operation were estimated using a Delphi method of local doctors and experts in each medical discipline. Disability-adjusted life years averted were calculated using the following formula. For deaths averted, we calculated

Life expectancy × likely threat to life
× efficacy of treatment

This formula is the same as has been used to calculate life years saved in other papers [18]. For those conditions that predominantly cause disability, we used the formula

Life expectancy × risk of permanent disability
× disability weight × efficacy of treatment

We used local life expectancies from the WHO Tables and disability weights from the Global Burden of Disease study [19]. We did not use age weighting or discounting in the base case analysis in line with the GBD study [20].

Calculation of costs

Capital costs

Actual building costs for Thyolo, and estimated building costs for Bo were obtained and depreciated over 20 years using a straight-line method. Equipment costs were estimated at 15% of the building costs and depreciated over 7.5 years [21].

Recurrent costs

For Thyolo, actual salaries were obtained from the hospital for all medical and non-medical staff within the hospital for the financial year beginning 2012. Other recurrent costs, including fuel, utilities and maintenance were obtained from the hospital on an "ideal" level, i.e. what was requested from the Ministry of Health rather than what was obtained. Equivalent estimates for Bo were obtained from reports on health system financing in Sierra Leone [22, 23].

Costs of medicines

Government district hospitals in sub-Saharan Africa tend to be underfunded, and therefore, we calculated "ideal" treatment rather than "actual" treatment. For each diagnosis, we identified the best treatment according to international or published guidelines. We costed the medicines using the WHO International Drug Price Indicator guide [24, 25], and calculated the costs of other materials, e.g. catheters, cannulas and intravenous lines from local price lists. As far as possible, we costed for the full course of treatment for all acute conditions, even if part or most of this would usually be delivered on an outpatient basis, e.g. 6 months of triple therapy for uncomplicated pulmonary tuberculosis, because we argue that partial treatment of such conditions could be detrimental. For chronic, long-term conditions such as epilepsy, we costed for inpatient or intravenous treatment and then for two weeks of outpatient oral daily medication, accepting that lifelong treatment for

Table 2 Weightings

Weighting given	Risk of death or permanent disability	Treatment efficacy
0	Condition fatal or permanently disabling <5% of the time	<5% chance of permanent cure
0.3	Condition fatal or permanently disabling 5–50% of the time	5–50% chance of permanent cure
0.7	Condition fatal or permanently disabling 50–95% of the time	50–95% chance of permanent cure
1	Condition fatal or permanently disabling >95% of the time	>95% chance of permanent cure

disease control would need to be found for each patient but was not part of inpatient hospital costs and therefore not part of our study. We assumed that most infections (e.g. pneumonia) would require minimum three days of intravenous high-dose antibiotics, followed by completion of an oral course, except for severe infections such as meningitis, where we costed for a minimum of a one week course of intravenous high-dose antibiotics. We used a mean cost per major surgical procedure of US$179 (2012 US$), used by Verguet et al. [26] and based on the unit cost of a caesarean section [27] as has been used in previous studies. All costs were converted to international dollars using the purchasing power parity for Sierra Leone and Malawi in 2012 [28].

Sensitivity analysis

We performed sensitivity analysis by recalculating the DALYs averted using the World Health Organization Guidelines for Cost-Effectiveness Analysis [29] with GBD disability weights and with and without age weighting and discounting at 3%, and using ideal life expectancies from the GBD study [30].

Ethical approval

This study received research ethics committee approval from the College of Medicine Research Ethics Committee, Malawi, and the Sierra Leone Ethics Committee.

Results

Table 3 outlines the estimated total annual costs for each hospital. A total of 97,844 DALYs were averted by Thyolo District Hospital compared with 36487 in Bo District Hospital (Table 4). The highest number of averted DALYs were in paediatrics (42 and 59%). 35% of all DALYs were averted in Bo by surgery and obstetrics/gynaecology, and 24% of DALYs in Thyolo. Total cost (US$)/DALY averted was 26 (range 17–66) for Thyolo and 363 (range 187–881) for Bo (Tables 5, 6).

Table 3 Annual costs for 2012 in US$

Item	Thyolo DH, Malawi	Bo DH, Sierra Leone
Capital costs		
Buildings	632,152	250,000
Equipment	270,923	107,142
Salaries	410,179	7,743,956
Recurrent costs (utilities, fuel, admin, maintenance, etc.)	1,836,591	5,416,362
Materials and medicines	226,272	160,719
Total (US$) per year	3,376,117	13,678,178

Table 4 DALYs averted per specialty in 6 months

Specialty	Number of DALYs averted (%)	
	Thyolo	Bo
Medicine	32,780 (34)	2301 (6)
Obstetrics/gynaecology	20,577 (21)	7138 (20)
Paediatrics	40,592 (42)	21,669 (59)
Psychiatry	534 (1)	21 (0)
Surgery	3361 (3)	5073 (14)
Paediatric surgery	n/a	285 (1)
Total	97,844	36,487

Discussion

This study suggests that government district hospitals in sub-Saharan Africa may be very cost-effective as defined by the World Health Organization [31] and in line with previous estimates. However, there are a number of limitations and discrepancies with our study. Our data do not show as high a proportion of DALYs averted from obstetric or surgical care than previously reported and there are likely to be a number of reasons for this. From the provider perspective, the provision of safe surgical care requires the presence of a number of factors, including trained surgical and anaesthetic providers, infrastructure, equipment and supplies for surgery and anaesthesia, de-contamination and sterilisation facilities, a safe and affordable blood supply, and trained nursing staff. From the patient perspective, patients present late with surgical conditions in Africa and are therefore not always amenable to surgical treatment or correction. Many patients never present at all for a variety of reasons ranging from the quality of the roads, medical beliefs and direct and indirect costs of treatment [32]. It is likely that fully funded, fully equipped hospitals would attract significantly more patients with conditions requiring surgical attention. In addition, we noted in a previous study the high proportion of patients with surgical conditions who abscond from hospital after diagnosis—38% with bowel obstruction, 39% with peritonitis and 20% with ectopic pregnancy [33] with previous studies on absconding suggesting there may be both cultural and financial reasons for this [34, 35]. Finally, comparison with the previous studies is difficult because of the widely differing contexts—both in the caseload of the hospital and the local disease demographics in different countries.

Further limitations to this study occur with respect to calculating DALYs and costs. Although both hospitals

Table 5 Sensitivity analysis

Method	DALYs averted Malawi[a]	DALYs averted Sierra Leone[a]
Baseline	97,843.55	36,487.36
WHO methodology—no age weighting/discounting	43,563.63	14,713.39
WHO methodology—with age weighting and discounting	25,682.63	7759.10
Baseline using local life expectancies	64,435.34	18,835.8

[a] Over 6 month period of study

Table 6 Overall cost-effectiveness per annum

Method	Cost/DALY averted Malawi	Cost/DALY averted Sierra Leone
Baseline (local life expectancies)	26	363
WHO methodology—no age weighting/discounting	39	465
WHO methodology—with age weighting and discounting	66	881
Baseline using ideal life expectancies	17	187

were highly cost-effective, the overall cost/DALY averted was quite different when the two are compared. There are a number of possible reasons for this. Surgical services were also available in nearby non-governmental hospitals, potentially reducing uptake for certain surgical conditions in government hospital services. As discussed in our previous paper, a nearby non-governmental hospital in Bo providing maternal health services meant that a significant number of obstetric admissions were referred there rather than treated in the government hospital. Conversely, national health policy in Sierra Leone provides free health care for under 5's and pregnant/lactating women, which is likely to have driven up the proportion of DALYs averted in Bo for these groups. However, although these were high (59 and 20% of all DALYs averted), they percentages were similar in Thyolo (42 and 21%). Costs are also problematic to calculate in this context as many low-income countries have very underfunded district hospitals, and therefore, calculating accurate costs for services is challenging. Furthermore, some NGOs provide additional funding either for salaries or for specific diseases. The much higher cost/DALY averted for Bo District Hospital was due to higher estimated salary costs and recurrent costs which may in part have been because we used estimated costs for these as it was not possible to obtain either actual or ideal costs.

DALYs themselves are problematic as discussed in detail elsewhere. We used estimates of likely threat to life and risk of permanent disability, along with likely effectiveness of treatment, based on Delphi method of local doctors and international experts. However, these may not have reflected the actual outcomes for individual patients. We attempted to calculate ideal treatment for a patient based on the diagnosis, and using the WHO Price Indicator, but this does not necessarily reflect the actual costs at local level of providing such treatment. Furthermore, often individual patients presenting with the same condition may require treatment for different lengths of time, or may develop complications of an illness which may require different treatment. We used a mean cost of a major surgical procedure of US$179, based on previous studies, but major surgical procedures can vary widely in actual costs, and the same procedure may cost differently in different patients. Certainly the study would have been methodologically stronger if it had been possible to perform it as a prospective study, observing actual costs to both provider and patient, as well as actual outcomes, but this was not practical with the resources available.

Finally, large numbers of patients were seen in both hospitals in the outpatient department—over a thousand a month in Thyolo alone—and it was not possible to incorporate these into the study. Thus, the overall number of DALYs averted if the outpatient workload as well as the inpatient workload had been taken into account would have probably made the overall cost-effectiveness higher.

Conclusion

This is the first published evidence of the cost-effectiveness of government district hospitals in sub-Saharan Africa and adds weight to the argument that Ministries of Health and the Donor Community should invest in government district hospitals in order to reduce mortality and disability from surgical conditions.

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Macroeconomic costs of the unmet burden of surgical disease in Sierra Leone: a retrospective economic analysis

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ABSTRACT

Objectives The Lancet Commission on Global Surgery estimated that low/middle-income countries will lose an estimated cumulative loss of US$12.3 trillion from gross domestic product (GDP) due to the unmet burden of surgical disease. However, no country-specific data currently exist. We aimed to estimate the costs to the Sierra Leone economy from death and disability which may have been averted by surgical care.

Design We used estimates of total, met and unmet need from two main sources—a cluster randomised, cross-sectional, countrywide survey and a retrospective, nationwide study on surgery in Sierra Leone. We calculated estimated disability-adjusted life years from morbidity and mortality for the estimated unmet burden and modelled the likely economic impact using three different methods—gross national income per capita, lifetime earnings foregone and value of a statistical life.

Results In 2012, estimated, discounted lifetime losses to the Sierra Leone economy from the unmet burden of surgical disease was between US$1.1 and US$3.8 billion, depending on the economic method used. These lifetime losses equate to between 23% and 100% of the annual GDP for Sierra Leone. 80% of economic losses were due to mortality. The incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80% were calculated to be between US$360 million and US$2.9 billion.

Conclusion There is a large economic loss from the unmet need for surgical care in Sierra Leone. There is an immediate need for massive investment to counteract ongoing economic losses.

Strengths and limitations of this study

- ► The Lancet Commission on Global Surgery estimated cumulative losses from unmet surgical need of US$12.3 trillion globally. This is the first country-specific study to estimate macroeconomic losses.
- ► Estimates of unmet need in this study are based on previous studies. It is not possible to be certain exactly what the unmet surgical need is.
- ► Likewise, true death and disability averted is impossible to be accurately determined and is based on estimates.
- ► All modelling strategies have their limitations, especially in resource-poor settings. Therefore, we used three different approaches for comparison.

INTRODUCTION

Although once described as the 'neglected stepchild of global health',[1] surgery is increasingly being recognised as an indivisible, indispensable part of healthcare.[2] Currently, surgical disease accounts for an estimated 33% of the global burden of disease,[3] with an estimated 5 billion people have no access to safe, affordable surgical care and anaesthesia when needed[4] and an estimated 143 million additional procedures needed in low/middle-income countries (LMICs) to save lives and to prevent disability.[5] Surgical access is weakest in low-income countries.[6] Although traditionally thought of as an expensive intervention, cost-effectiveness analyses have shown that surgeries—both individual procedures and surgical platforms—are cost-effective when compared with other widely implemented health interventions.[7]

A number of studies have shown the profound economic impact on individuals and households resulting from untreated surgical conditions, with resulting death and disability.[8 9] However, treatment of such conditions can improve the quality of life, household income as well as social status.[10] Reducing deaths and disability from road traffic accidents alone in LMICs to the level of high-income countries would result in a potential economic saving of US$758–786 billion per year.[11] If there is no accelerated urgent scale up of surgical services, LMICs are estimated to lose a cumulative US$12.3 trillion to their economies over the next 15 years.[5]

To date, there have been no country-specific estimates of the economic costs resulting from loss of productivity due to death and disability from surgically treatable disease. Sierra Leone has been estimated to have a

Table 1 Weightings definition

Weighting given	Risk of death or permanent disability	Treatment efficacy
0	Condition fatal or permanently disabling <5% of the time	<5% chance of permanent cure
0.3	Condition fatal or permanently disabling 5%–50% of the time	5%–50% chance of permanent cure
0.7	Condition fatal or permanently disabling 50%–95% of the time	50%–95% chance of permanent cure
1	Condition fatal or permanently disabling >95% of the time	>95% chance of permanent cure

high burden of surgical disease, with a household survey suggesting that 25% of deaths in the previous year may have been averted by timely surgical intervention, and 25% of respondents claiming to have a surgical condition requiring attention.[12] Results from a national survey reported that there were 24 152 operations in Sierra Leone in 2012 across all hospitals (government and private) amounting to a national average of 400 operations per 100 000. This amounts to approximately 8% of surgical disease treated and 92% untreated. Our aim was to estimate the likely impact on the Sierra Leonean gross domestic product (GDP) resulting from this untreated surgical disease.

This study is carried out in the context of slow improvements in health and economic indicators for Sierra Leone compared with other West African countries. Although life expectancy at birth increased from 41 to 51 years between 2002 and 2014, this remains the lowest life expectancy of any country assessed by WHO.[13] Malnutrition, communicable diseases and poor maternal and child health services cause substantial mortality and morbidity each year.[14] The country has a growing and youthful population driven by a high total fertility rate of almost five children per woman, yet a small and largely agrarian economy underuses this potential of its workforce with an estimated 60% youth unemployment attributable to poor educational outcomes, a lack of private sector jobs and low pay.[15] Sierra Leone ranks 179 out of 188 countries included in the United Nations Development Programme's Human Development Index, a composite ranking of health, educational and economic outcomes by country.[16]

METHODS

Disability-adjusted life year

The disability-adjusted life year (DALY) is a composite measure of health quantity and quality which seeks to capture the negative consequences of premature mortality alongside burden from morbidity for the duration of an illness:

$$\text{DALYs} = \text{YLD} + \text{YLL} \quad (1)$$

$$\text{YLD} = \text{I} \times \text{D} \times \text{DW} \quad (2)$$

$$\text{YLL} = \text{N} \times \text{LD} \quad (3)$$

where YLD is the number of years lost due to disability, I the incidence of a condition, D the duration of illness, DW the disability weight, YLL the years of life lost, N the number of deaths from a condition and LD the life expectancy at age of death. DALYs are sometimes weighted differently according to the age at which a person dies in theory to reflect societal values around death at younger age. This is a controversial topic in the calculation of DALYs and, as in WHO Global Burden of Disease (GBD) studies since 2001, we do not apply age weighting in this analysis. We used local life expectancies from WHO's Life Table for Sierra Leone in 2012[13] and disability weights published by the GBD Study.[17]

Details of all operations performed in Sierra Leone in 2012 from every surgical provider was obtained from a nationwide, retrospective study.[18] Data were excluded if there was no recorded age for the patient or no recorded operation. The remaining records were then analysed. For each operation, we used a weighting system used by previous authors[19 20] to determine the likely threat to life without treatment, the likelihood of permanent disability and the likely efficacy of treatment (table 1). Operations were deemed to either avert death or disability as in table 2. Weights for each operation were estimated using a Delphi method of local doctors and experts in each field. Operations were weighted differently depending on whether they were 'emergency' or 'planned' operations. Those where it was unclear whether it was performed as a planned or an emergency operation were weighted as for a 'planned' operation. Assumptions for each operation are shown in table 2. Disability weights for conditions primarily causing disability were obtained from the Global Burden of Disease Study.[17]

Methods for calculating economic losses

A number of methods are available to calculate economic losses due to preventable health conditions, and we opt to take three approaches which are simple and transparent in nature.

Acknowledging the breadth of literature in this area, we use three different approaches to estimate productivity losses from unmet surgery need: two applying the human capital approach (HCA), first using inputs of GDP/capita and second lifetime earnings forgone, alongside a method incorporating the value of a statistical life.

Both HCA approaches use national accounts or workforce participation and earnings data and do not require extensive assumptions around the structure of the Sierra Leonean economy. These methods may therefore underestimate economic losses because they do not capture dynamic effects of reductions in morbidity or mortality,

Table 2 Delphi weights for primarily death-averting and primarily disability-averting operations with assumptions on earnings

	Threat to life	Treatment efficacy	Risk of permanent disability	Assumption on earnings
Primarily death averting				
Appendectomy	0.7	1.0		
Caesarian section	0.3	0.7		
Cervical or vaginal laceration	0.1	1.0		
Chest tube	1.0	1.0		
Dilatation and curettage	0.3	0.7		
Hernia repair (emergency)	0.7	1.0		
Hysterectomy	0.3	0.7		
Laparotomy—emergency	1.0	0.7		
Laparotomy—elective	0.3	0.3		
Malignancy	1.0	0.3		
Manual placenta removal	0.3	0.7		
Neonatal surgery (emergency)	1.0	0.7		
Repair of ruptured uterus	1.0	1.0		
Ectopic pregnancy	0.7	1.0		
Tracheostomy	1.0	0.7		
Amputation of limb	1.0	0.7		
Primarily disability averting				
Cataract surgery		0.7	0.7	60% lifetime earnings lost
Cleft lip repair		0.7	1.0	No impact (no literature found)
Cystostomy		1.0	0.7	No impact (no literature found)
Fracture		0.7	0.7	88% of earnings lost for 1 year
Hernia repair (planned/unknown)		0.3	1.0	18% (16%–20%) lifetime earnings lost
Neonatal surgery (planned/unknown)		0.7	0.7	No impact (no literature found)
Obstetric fistula repair		0.7	1.0	97% lifetime earnings lost
Urethral stricture dilation		0.3	1.0	No impact

for example, the economic productivity from additional children of persons whose death is delayed by surgery. The methods are consistent with the growing consensus in health economic evaluation that the societal perspective should be considered where possible to give a more accurate reflection of true economic losses to society, outside of direct health expenditure.[21]

The value of a statistical life (VSL) is the amount of money a person or society is willing to spend to save one life and is commonly used by public bodies to value lives saved in cost–benefit analyses of health, transport or environmental projects.[22] Data often come from the labour market, where individuals sometimes make decisions that involve a trade-off between financial rewards and an increased risk of premature mortality. Economists use this revealed preference for risk to calculate their VSL, reflecting the amount individuals are willing to pay to avert the risk of dying. For example, if a welder on an oil rig was willing to accept a pay cut of £1000 to work on land where the risk of death was 0.001 lower, their VSL would be £1 million (£1000/0.001). VSL estimates are often larger than production-based measures of welfare losses (including the HCA) but fit better into welfare economic frameworks because they allow the worth of individuals to be greater than their wage rate.

We present economic losses both as an absolute number for income loss discounted to 2014 US$ and as a percentage of GDP; however, we note caution in interpreting the latter. Household earnings (and subsequent consumption) are elements of GDP calculations, alongside aggregate government expenditure and business investment, among others. As elsewhere in the literature,[23] we use the comparison between projected losses and actual GDP as a useful relative frame to understand the large numbers produced by this model. However, we emphasise that these are not directly causal and, in fact, may understate the direct effect of unmet surgery need on GDP. Finally, we compare figures to the 2014 GDP of Sierra Leone due to the anticipated negative impact of Ebola virus disease on the Sierra Leonean economy.[24]

Table 3 Total number of disability-adjusted life years averted by operation

	No of operations in 2012
Primarily death averting	
Amputation	234
Appendectomy	1114
Caesarian section	2646
Cervical or vaginal laceration	24
Chest tube	35
Dilatation and curettage	508
Hernia repair (emergency)	166
Hysterectomy (all)	218
Laparotomy (all)	815
Malignancy	173
Manual placenta removal	65
Necrosectomy	1
Neonatal surgery (emergency)	13
Manual placenta removal	8
Salpingectomy for ectopic pregnancy	10
Ectopic pregnancy	103
Tracheostomy	8
Primarily disability averting	
Cataract surgery	2242
Cleft lip repair	2
Cystectomy	16
Fracture	964
Hernia repair (planned/unknown)	3435
Neonatal surgery (planned/unknown)	5
Obstetric fistula repair	201
Urethral stricture dilation	59
Total	13 065

Modelling approach

The need for surgery in Sierra Leone was calculated from two cluster randomised, cross-sectional, countrywide surveys.[12 25] First, we generate a counterfactual scenario where all annual mortality and disability is avoided by assuming current met need is 8%, as estimated by Bolkan *et al*,[18] although this is likely to be a conservative estimate. Then, we present different scenarios of met need according to published studies and benchmarks, aggregating reductions in mortality and morbidity separately.

The literature has not reached consensus on how to estimate productivity losses due to morbidity.[22] We take a pragmatic approach and obtain condition-specific data from the literature to estimate the proportion of persons with surgically treatable conditions who were unable to work following the development of a condition (table 2). Where no evidence of productivity effects are noted, we take a conservative approach and assume that untreated persons do not suffer productivity losses. Further information is provided in online supplementary file 1.

ESTIMATION OF ECONOMIC LOSSES

We use three methods to estimate economic losses:

Gross national income per capita

A common application of the HCA, recommended by the WHO Commission on Macroeconomics and Health, is to use gross national income (GNI) per capita to estimate the potential economic gains from gaining an additional year of life.[26] This approach has been applied elsewhere to estimate economic gains and losses of health interventions. Although the GNI/capita approach may undervalue benefits from averting a DALY as it does not account for externalities on the wider labour market or care required from family members, the method is transparent and broadly accepted in the literature.[22] Thus, GNI/capita approximates the economic value that the average individual adds to a society per year, and we simply multiply GNI/capita by the number of DALYs averted in each scenario of met surgical need.

Lifetime earnings forgone

The GNI/capita approach does not necessarily equate to the majority of individuals' economic productivity, particularly in unequal economies such as Sierra Leone, where few very productive individuals may bias mean earning estimates. Therefore, we calculate the present value of lifetime earnings (PVLE) forgone for each age category, slightly adapting the model presented in Menzin *et al*.[27]

$$\mathrm{PVLE}_{\mathrm{paid}}(i,j,k) = \sum_{i=s_j}^{n_j} \frac{(l_{i,j,k} * w_{i,j,k})}{(1+r)^{i-s_j}} \quad (4)$$

where the estimated losses for a cohort of persons with age i, gender j, working in employment sector k and with life expectancy s_j are a weighted average of their economic activity, l, and wage rate w. We split each gender into five age groups, driven by the availability of data on avertable mortality and morbidity and use the midpoint of each strata to estimate years of productive life remaining.

We use data from the nationally representative 2011 Sierra Leone Integrated Household Survey (SLIHS)[28] to obtain estimates of labour force participation by gender. We estimate the proportion of the population not in the labour force, the proportion employed in agriculture and the proportion in other waged industry. For both employed groups, we use SLIHS data to calculate the number of hours worked per year and apply earnings and salary data to estimate total annual earnings.

Value of a statistical life

A number of methods exist to calculate the VSL in Sierra Leone, which are briefly summarised in online supplementary table 1. For our main analysis, we use $90 700 as calculated for sub-Saharan Africa by Robinson and Hammit.[29] We follow Alkire *et al*[30] and convert this VSL

Table 4 Summary of met surgical need in 2012

Age (years)	Deaths averted in 2012	Mortality DALYs averted due to surgery in 2012 (YLL)	Morbidity DALYs averted due to surgery in 2012 (YLD)
1–4	58	1073	293
5–15	214	3877	741
16–19	278	4936	566
20–33	778	13 086	2225
34+	332	5173	3626

DALYs, disability-adjusted life years; YLD, years lost due to disability; YLL, years of life lost.

into its annualised equivalent, the value of a statistical life year, for use with DALYs. Here, we assume that the VSL is analogous to an annuity, giving a constant stream of income of $31 415 per year (5% discount rate). Consistent with DALY calculations, we do not apply age weighting to this value so assume it remains constant throughout a lifetime. The use of Sierra Leonean data negates the rescaling of VSL from the USA, as elsewhere.[29 31]

Discount rate

The choice of discount rate can have a large impact on the results of an economic analysis, particularly when benefits or costs occur a long time after initial expenditure.[32] We use a discount rate of 5% on costs and benefits. We explore the effect of higher discount rates in a sensitivity analysis.

Uncertainty and sensitivity analyses

We use a deterministic sensitivity analysis to explore methodological uncertainty stemming from the choice of discount rate, exploring a zero discount rate, 3% as per guidelines and 8.7% to mirror the local inflation rate. We carry out a multivariate probabilistic sensitivity analysis with 1000 Monte Carlo simulations of a number of variables simultaneously to assess the impact of parameter uncertainty on model predictions and present included parameters and distributional assumptions in online supplementary table 2.

RESULTS

Met need in 2012

Out of the 24 152 operations recorded as being performed in Sierra Leone in 2012, 46% were excluded—5672 because of a lack of detail about the operation and 5415 because there was no age recorded. We assumed that the 54% analysed were representative of the unmet need. Of the remaining operations, 6141 were death averting and 6924 were disability averting (table 3). Accounting for the probability of success in death-averting operations, 2219 deaths were averted through surgical intervention in 2012 (table 4).

Health losses due to unmet need

Assuming that the 24 152 operations recorded in 2012 represent 7.9% of met surgical need in Sierra Leone,[18] we estimate that unmet surgical need in 2012 resulted in 766 606 DALYs forgone: 606 981 DALYs lost due to mortality and 159 625 due to morbidity. If surgical provision could be increased to 80% in line with the recommendations of the Lancet Commission on Global Surgery, an additional 599 953 DALYs would be averted compared with 2012 provision. Reaching the goal of 50% provision would avert an additional 349 972 DALYs, while the pragmatic target of 20% provision would result in 99 992 additional DALYs averted.

Economic losses

Figure 1 presents estimated discounted economic losses from unmet surgery need. As anticipated, using different approaches to estimate losses, resulted in vastly different figures. The value of a statistical life approach gave the highest figure: current economic losses due to unmet surgery need were estimated to be $3.8 billion (all monetary figures presented as 2012 US$), equivalent to 107% of Sierra Leone's GDP in 2012. The GNI/capita approach put forward by the WHO Macroeconomic Commission gave the next highest figure of $1.4 billion (42% of 2012 GDP), while the lifetime earnings forgone method gave an estimate of $1.1 billion (31% of 2012 GDP). Economic losses due to mortality contributed to around 80% of total economic loss from unmet need across all measures. Finally, table 5 presents the incremental losses that would be averted if surgical provision were to be scaled up to each of the three target scenarios.

Sensitivity analyses

Figure 2 displays results from a one-way sensitivity analysis, analysing the change in estimates of unmet need as model parameters are varied in isolation. Estimates are particularly sensitive to assumptions of current unmet need and whether the productivity estimates consider morbidity in addition to mortality. Assumptions of earnings do not make a substantive difference to estimates using the lifetime earnings forgone method.

Figure 3 displays the results of a probabilistic sensitivity analysis alongside base case estimates, while error bars illustrate the 25th and 75th quartiles of Monte Carlo model runs. When accounting for parameter uncertainty in the Probabilistic Sensitivity Analysis (PSA), the model still predicts substantial economic losses due to unmet surgical need. Of all probabilistic simulations, 38% of estimates were greater than the deterministic estimate. The variability of VSL simulation estimates is between 61% and 73% greater than that of human capital approaches.

DISCUSSION

In 2013, the Lancet Commission on Investing in Health argued that investing in healthcare in LMICs produced profound returns on investment of between

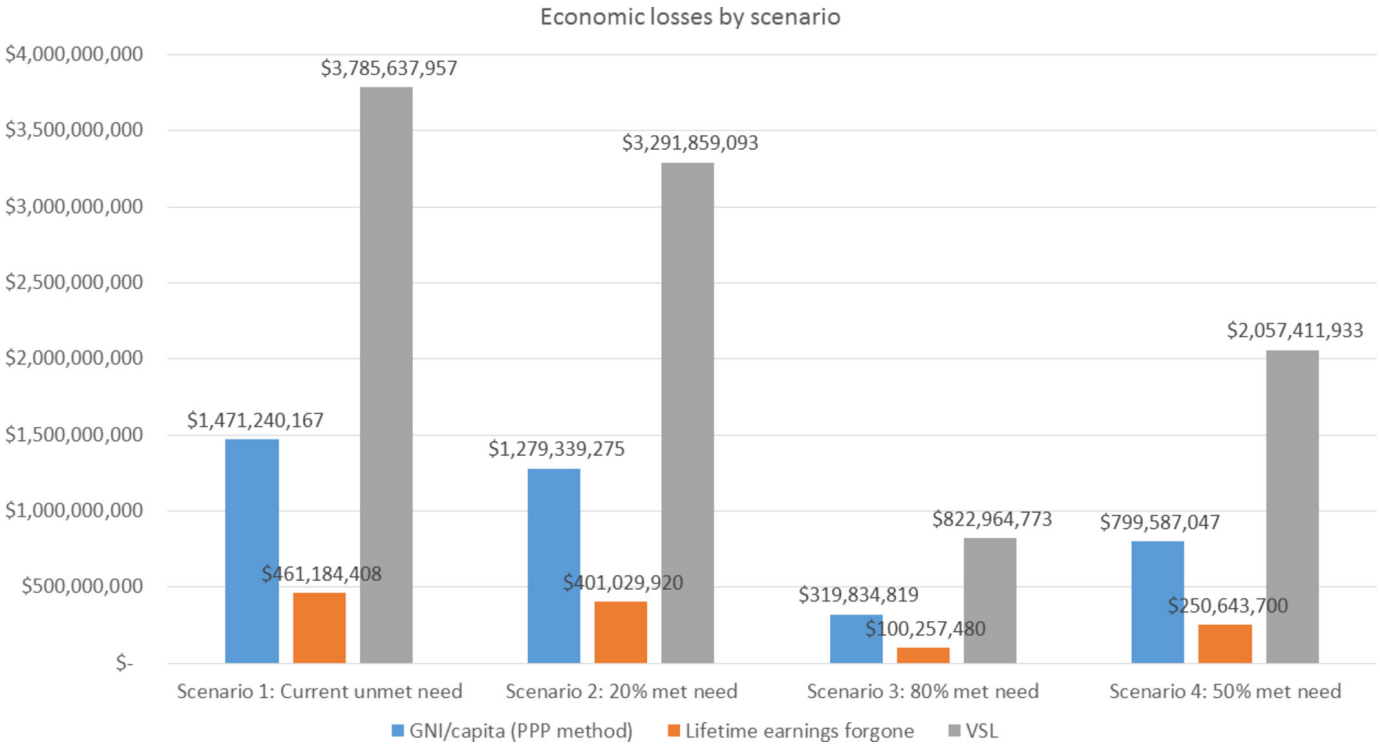

Figure 1 Estimated discounted lifetime economic losses due to unmet surgery need by scenario. GNI, gross national income; ppp, purchasing power parity; VSL, value of a statistical life.

US$9 and US$20 for every dollar invested.[33] The question thus arose as to whether investment in the provision of surgical services to avert death and disability would give a similar financial return on investment. This question was addressed by the Lancet Commission on Global Surgery which presented data on both the economic impact of untreated disease and the financial commitment required to scale up surgical services. Alkire *et al* calculated projected economic losses in LMICs from a variety of surgical conditions using the value of lost output approach of up to 2.5% of annual GDP and 17% of 2010 GDP if a value of lost welfare approach was used.[34] Verguet *et al*[35] modelled the possible scale up of surgical services in LMICs for the Lancet Commission on Global Surgery target of 5000 operations per 100 000 population per year and calculated that costs of US$300–420 billion would need to be met to achieve scale up over the years 2012–2030, representing 4%–8% of total annual health expenditure. This large investment in scaling up surgical services across 88 LMICs was positive when compared with the $12.3 trillion loss to economic growth in these countries if surgical service development was neglected. The Lancet Commission on Global Surgery data presented a similar picture presented to the Lancet Commission on Investing in Health—investing in surgical care was beneficial and produced significant economic returns on investment.

The few studies that have been published on the macroeconomic impact of surgical disease in LMICs all show significant costs to national economies.[11 34] This study demonstrates significant estimated costs to the economy of Sierra Leone from untreated surgical disease. It is the first single-country study and also represents a move away from modelled data to the use of primary surgical data for an estimation of the economic impact of untreated disease. The economic impact of untreated surgical disease in Sierra Leone is significant. In 2012, the estimated cumulative loss to the Sierra Leone economy from the unmet burden of surgical disease was between US$1.1 and US$3.8 billion, depending on the economic method used. This equates to between 23% and 100% of the 2012 GDP for Sierra Leone. Eighty per cent of

Table 5 Incremental losses averted by scale up of surgical provision compared with current met need

Incremental economic losses averted	Scenario 2: 20% met need	Scenario 3: 80% met need	Scenario 4: 50% met need
GNI/capita (ppp)	$191 900 891	$1 151 405 348	$671 653 120
Earnings forgone (LYL only)	$60 154 488	$360 926 928	$210 540 708
Value of a statistical life approach	$493 778 864	$2 962 673 184	$1 728 226 024

GNI, gross national income; LYL, life years lost; PPP, purchasing power parity.

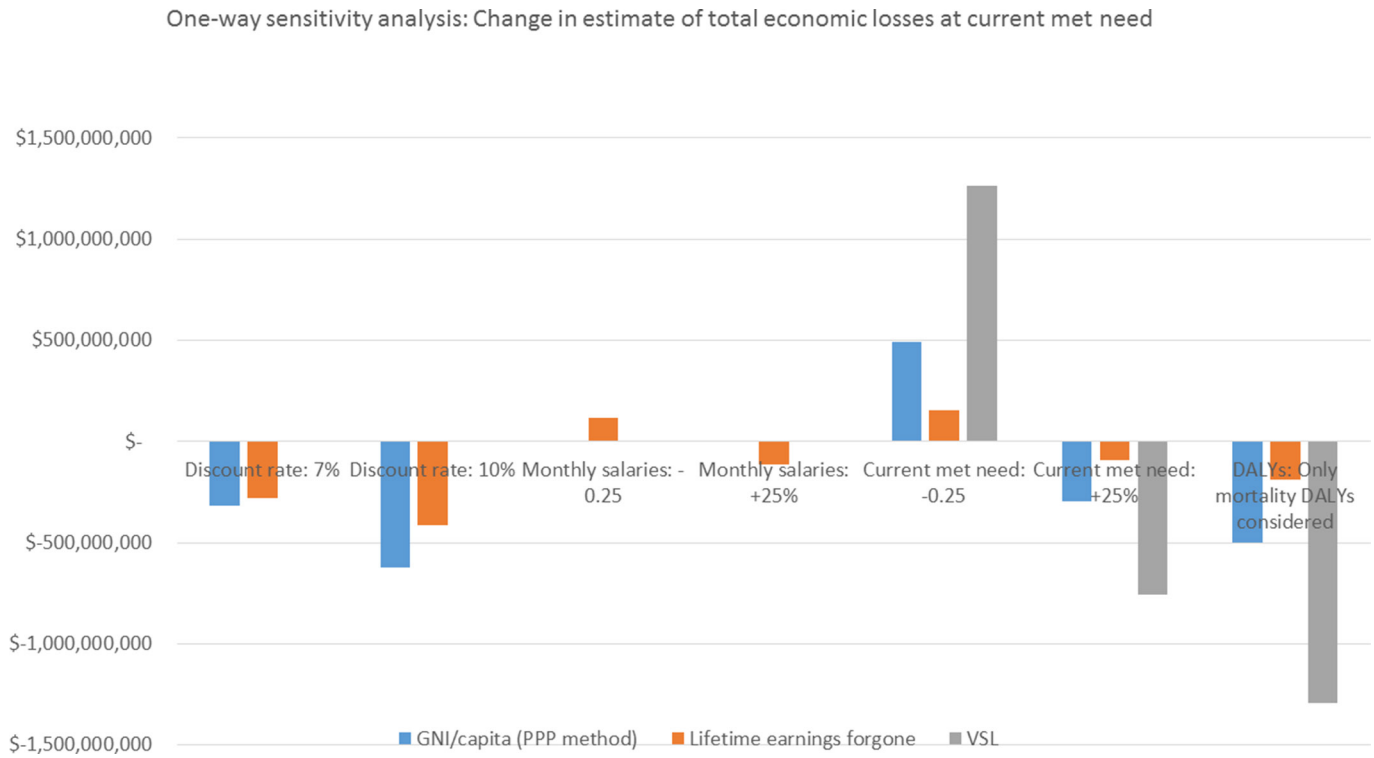

Figure 2 One-way sensitivity analysis. DALYs, disability adjusted life years; GNI, gross national income; ppp, purchasing power parity; VSL, value of a statistical life.

economic losses were due to mortality. The incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80% were calculated to be between US$360 million and US$2.9 billion, accepting that the Lancet Commission target was for 80% access to the Bellwether procedures, not for all surgery.

There are a number of limitations to this study. First, we had to discard 46% of the surgical data because they

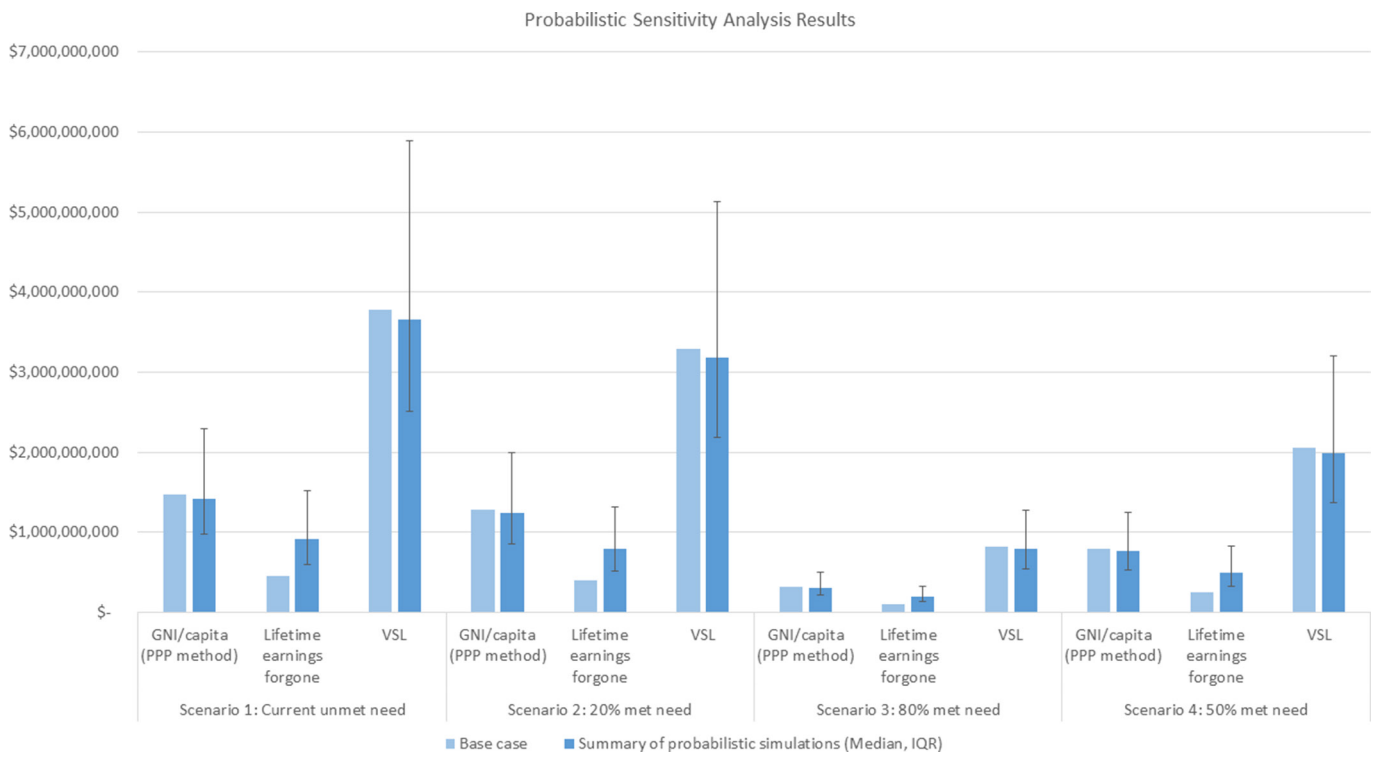

Figure 3 Probabilistic sensitivity analysis. GNI, gross national income; ppp, purchasing power parity; VSL, value of a statistical life.

were incomplete. As a result, we worked with only 54% of the surgical data, which may not have been fully representative and may have skewed the results. We assumed that the 54% accounted for the 7.9% of met need and calculated unmet need based on this, although of course, if we had a full complement of data, the met need and hence the unmet need would have been significantly greater.

Where data were absent, for example when the age of patients was recorded but not their gender, we used complete data observations to weight how these were distributed across groups at the lowest level of aggregation available, for example, by age group. If observations were missing not at random (type 2 error), this could introduce bias into our estimates. We assumed operations not listed as either 'emergency' or 'planned' were planned, so as to create a conservative estimate of the overall economic impact. In practice, many of these may have been emergencies and would have made the resulting economic losses even greater. We assumed that the same proportion of met and unmet need was uniform across all operations. However, it may be that the proportion of met: unmet need may be higher for certain operations because of the nature of the pathology and the urgency for example, free healthcare for pregnant women might mean that the ratio of met: unmet need is higher for caesarean sections than it is for emergency laparotomy. We also assumed that treating a treatable condition would return the patient back to full economic productivity, although this may not be the case.

There is substantial variation between estimates of economic losses depending on the methodology used, despite all methods using an equivalent estimate of DALYs attributable to unmet need. The VSL method places the greatest value on each DALY incurred and by definition leads to the largest estimate of economic loss. The human capital approaches, using estimates of GNI/capita and lifetime earnings foregone, place a small cost on the loss of each DALY and produce smaller estimates. In addition, economic losses estimated here do not consider the value of unpaid or domestic work because of uncertainty in assumptions required and because these do not form part of many estimates of GDP. In addition, our use of financial measurements of economic productivity is a limitation in the largely agrarian economy of Sierra Leone. Other metrics, which cannot be easily valued in financial terms such as food insecurity or the distribution of labour within the household, may capture potentially important aspects of economic productivity. Omitting these factors makes our model more conservative and we are likely to underestimate total economic losses, with a greater underestimation occurring in female groups.

Averages (mean values) are used to parameterise the model, and we therefore do not account for heterogeneity in estimates except for between genders and the age at which surgery was required. Other literature has shown a notable correlation between propensity for ill health and income, particularly in low/middle-income contexts such as this study, and this model does not account for this. The lifetime earnings estimates in the human capital approach may overstate losses and therefore assume that premature mortality or morbidity causes a lifetime's impact to the economy. With more data, we could have used a friction cost method to be more conservative; however, the lost earnings estimates are the lowest produced in this study.

Despite these limitations which are prevalent in much of the global surgical literature, we have provided the first national study of economic losses based on as much data as is currently available for Sierra Leone. This suggests massive economic losses, much of which may be avertable by the provision of timely, surgical care. What is now required is the development of a costed national surgical plan as recently undertaken in Zambia. In the case of Sierra Leone, the necessary investment might be more than the Lancet Commission on Global Surgery figure of 4%–8% of total annual health expenditure as there is likely to be a large initial capital outlay as well as a very significant necessary investment in the surgical workforce. Only then will we be able to compare this required investment with our economic loss figures to quantify the return on surgical system investment in terms of lives saves and disability averted.

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