World J Surg (2014) 38:252–263
DOI 10.1007/s00268-013-2243-y

World Journal of Surgery

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

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Published online: 8 October 2013

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

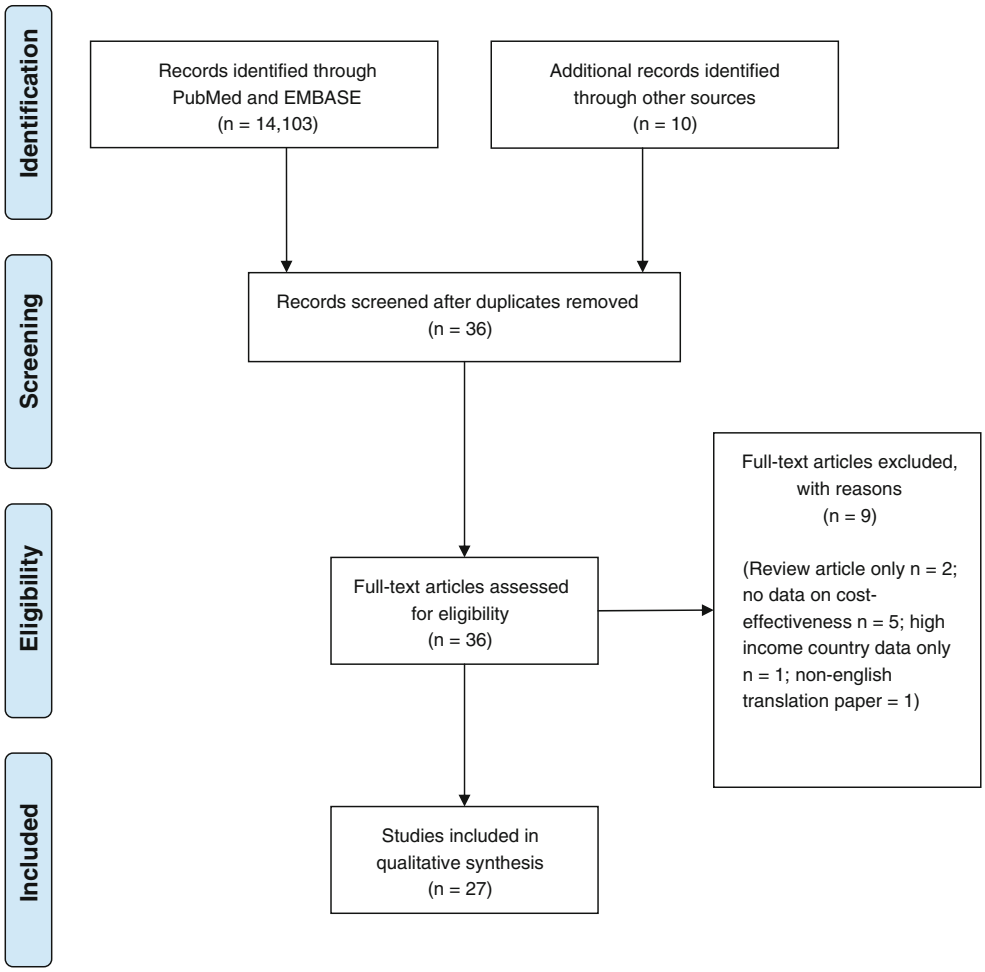

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram

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

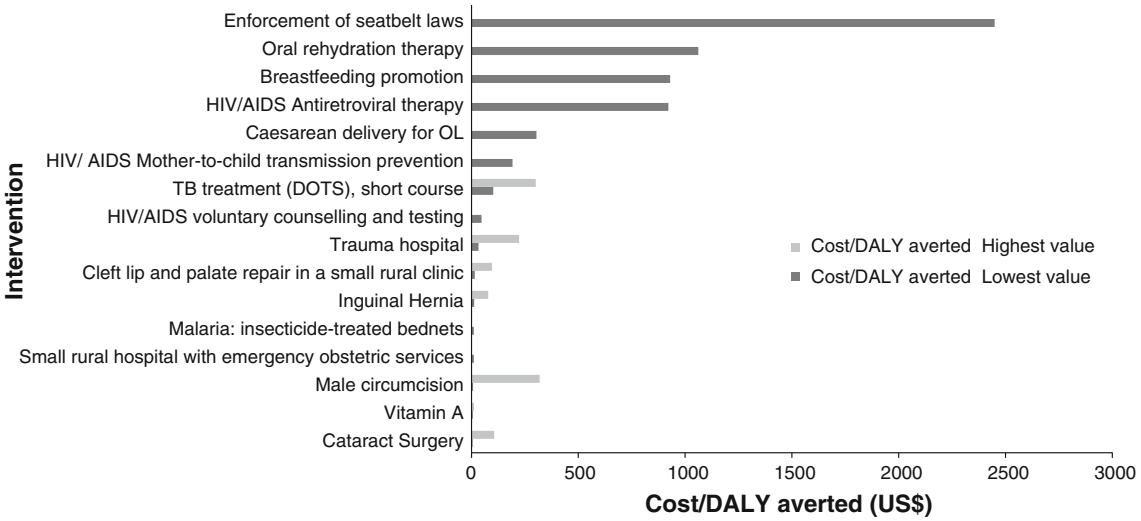

Fig. 2 Cost-effectiveness of surgical interventions compared with other public health interventions

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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