# Cost-effectiveness of surgery and its policy implications for global health: a systematic review and analysis

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## Summary

**Background** The perception of surgery as expensive and complex might be a barrier to its widespread acceptance in global health efforts. We did a systematic review and analysis of cost-effectiveness studies that assess surgical interventions in low-income and middle-income countries to help quantify the potential value of surgery.

**Methods** We searched Medline for all relevant articles published between Jan 1, 1996 and Jan 31, 2013, and searched the reference lists of retrieved articles. We converted all results to 2012 US$. We extracted cost-effectiveness ratios (CERs) and appraised economic assessments for their methodological quality using the 10-point Drummond checklist.

**Findings** Of the 584 identified studies, 26 met full inclusion criteria. Together, these studies gave 121 independent CERs in seven categories of surgical interventions. The median CER of circumcision ($13·78 per disability-adjusted life year [DALY]) was similar to that of standard vaccinations ($12·96–25·93 per DALY) and bednets for malaria prevention ($6·48–22·04 per DALY). Median CERs of cleft lip or palate repair ($47·74 per DALY), general surgery ($82·32 per DALY), hydrocephalus surgery ($108·74 per DALY), and ophthalmic surgery ($136 per DALY) were similar to that of the BCG vaccine ($51·86–220·39 per DALY). Median CERs of caesarean sections ($315·12 per DALY) and orthopaedic surgery ($381·15 per DALY) are more favourable than those of medical treatment for ischaemic heart disease ($500·41–706·54 per DALY) and HIV treatment with multidrug antiretroviral therapy ($453·74–648·20 per DALY).

**Interpretation** Our findings suggest that many essential surgical interventions are cost-effective or very cost-effective in resource-poor countries. Quantification of the economic value of surgery provides a strong argument for the expansion of global surgery's role in the global health movement. However, economic value should not be the only argument for resource allocation—other organisational, ethical, and political arguments can also be made for its inclusion.


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See **Comments** page e302

See **Online** for author interview with Tiffany Chao

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## Introduction

Global health efforts, guided in part by the Millennium Development Goals (MDGs),[1] have focused mainly on the prevention and treatment of malnutrition, obstetric disorders, and communicable diseases.[2] With the exception of a few surgical procedures—eg, caesarean delivery and male circumcision, which have a role in the prevention of maternal and neonatal deaths and the transmission of some communicable diseases—surgical interventions have been largely ignored. However, findings from the Global Burden of Disease 2010 study show that the growing burden of both non-communicable diseases and injuries includes many surgically treatable problems.[3] For example, road-traffic injuries accounted for 75·5 million disability-adjusted life-years (DALYs) in 2010, up nearly 20 million DALYs from 1990. Cancer has caused 76% more disability globally in the same timeframe. Historically, surgically treatable disease was estimated to account for at least 11% of the total global burden of disease,[4] which might be an underestimate because other studies have reported that about 25% of people in Sierra Leone need surgical assessment,[5] and as many as 85% of paediatric patients in Africa have a surgically treatable disorder by the age of 15 years.[6] The substantial and growing burden of surgically treatable disease necessitates careful assessment of a wide range of surgical interventions to establish their priority within the expanding global health movement.[7]

The perception of surgery as an expensive intervention might be a barrier to widespread acceptance of its potential role in achieving global health goals, especially when compared with other public health measures such as vaccines or antiretroviral treatment.[2,8] Assessment of the value of surgery in these settings is further challenged by uncertainty about the epidemiology of met and unmet need worldwide, the effectiveness of surgical intervention in the prevention of death and disability, and established benchmarks for quality of surgical care.[9]

Cost-effectiveness analysis might help to establish the value of surgical intervention because it takes into account both cost and health impact simultaneously in a validated and transparent framework.[10] Mock and colleagues proposed that cost-effectiveness of surgical procedures be considered, along with burden of disease and success of surgical intervention, to prioritise various surgical interventions in resource-poor countries.[11] Investigators doing cost-effectiveness research have analysed a range of surgery-related expenditures in low-income and middle-income settings, from short-term volunteer-led projects focusing on procedures for single diseases such as cleft palate or cataracts[12–14] to the existence of surgical facilities[15–18] to the potential implementation of surgical interventions internationally.[19–25] Stakeholders and policymakers have to consider a wide variety of factors when allocating funds and resources, and they would benefit from improved estimates of the prevalence of surgically treatable diseases and better information about the cost-effectiveness of surgery.

Various metrics have been proposed to calculate the health-benefit component of the cost-effectiveness equation when assessing a proposed intervention. The simplest is life-years (LY) gained, but this metric does not account for an intervention's ability to reduce morbidity. Summary measures of health that account for both survival and quality-of-life improvements include the quality-adjusted life year (QALY),[26] handicap-adjusted life year (HALY),[27] and DALY.[28] DALYs are calculated by adding the number of years of life lost due to premature mortality to the number of years of healthy life lost related to disability. Thus one DALY is defined as the loss of the equivalent of 1 year of life at full health.[29] The strengths and limitations of the DALY approach have been described previously.[27,30] Nevertheless, DALYs have become the most commonly used metric of health impact[31,32] and have been promoted by both the Disease Control Priorities Project[4] and WHO's Global Burden of Disease project.[7]

The evidence base for the cost-effectiveness of surgery in low-income and middle-income countries[33] is incomplete because no study has incorporated rigorous quality assessment and analysis.[34] We aimed to systematically compile and compare the cost-effectiveness of different surgical interventions, to objectively assess the rigour with which such studies were done, and to do a thorough analysis of existing data to mediate the divergent findings in previous cost-effectiveness studies.

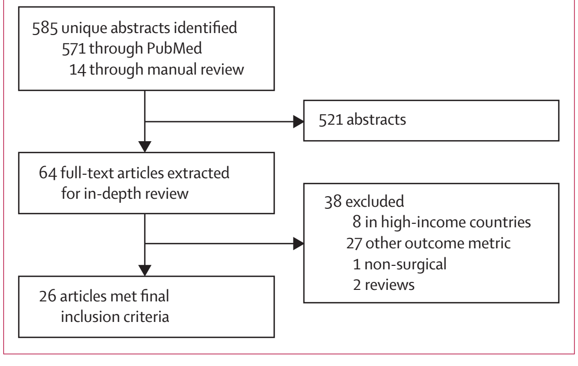


*Figure 1:* **Study selection**

## Methods

### Search strategy and selection criteria

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[17] We searched Medline using the following MeSH headings: "Surgical", "Surgery", "Costs and cost analysis", "Cost-benefit analysis" (inclusive of the subheading "cost effectiveness"), "Health care costs", and "Developing countries". We identified more articles by consulting experts and manually reviewing bibliographies of retrieved studies. We did our last search on Jan 31, 2013.

Inclusion criteria were as follows: studies that analysed the cost-effectiveness or cost-benefit of surgical procedures, presence of surgical facilities, or surgical missions; measured health benefit in LYs, QALYs, HALYs gained, or DALYs averted; were done in low-income and middle-income countries as defined by the World Bank;[33] and were published since 1996. Exclusion criteria were as follows: any study consisting of a narrative review or editorial lacking formal analytic methodology or using a different measure of health benefit.

### Quality assessment and data extraction

We appraised economic assessments for their methodological quality using the Drummond 10-point checklist, a standard method for the assessment of cost-effectiveness studies.[10] Some checklist items have both cost and consequence components; for these items, each component is weighted at 0·5 times, such that the final denominator is 10. If a component was not applicable, we weighed the complementary component at times 1.

We converted results from all studies that described cost-effectiveness in US$ per DALY, HALY, or QALY from their initial values in the study's reported currency to 2012 US$ using the Consumer Price Index Inflation calculator.[35] In some studies, the currency year was not stated and was therefore assumed to be the year of a study's publication. The studies that used international dollars did not include enough detail about what fraction of costs were non-tradable—we converted these costs into US$ and accordingly compared them using the Atlas method gross domestic product (GDP) per head.

To extract as much information as possible, we separated results from different countries or procedures even if they were reported in the same study; we regarded these results as separate data points when calculating medians. We included values for surgical interventions not combined with medical treatments only. We excluded data points from high-income countries only. Whenever possible, incremental DALY calculations using age weighting and 3% discounting were chosen for point values, and calculations without discounting and age

| | Year | Intervention | Country | GDP per head* | Cost per outcome | Unit of outcome | Currency | Cost per outcome in 2012 US$ |
|---|---|---|---|---|---|---|---|---|
| **General or other** | | | | | | | | |
| Jha et al[36] | 1998 | Caesarean delivery; appendectomy; hernia repair; trauma | Guinea | $313 | $18 / caesarean delivery; $36 / appendectomy; $74 / hernia; $278 / severe trauma | LY | 1994 US$ | $28; $56; $115; $431; |
| Gosselin et al[17] | 2006 | Surgical hospital | Sierra Leone | $243 | $32·78 | DALY | 2004 US$ | $39·84 |
| Debas et al[4] | 2006 | Injury, obstetrics, cataracts or glaucoma, cancer, perinatal conditions, congenital anomalies, other | Global | $887 | $212–241 in community hospital; $33–94 in district hospital† | DALY | 2001 US$ | $275–312 $43–122 |
| Gosselin et al[15] | 2008 | Trauma hospital | Cambodia | $479 | $77·40 | DALY | 2006 US$ | $88·15 |
| Gosselin et al[16] | 2010 | Trauma centre | Nigeria; Haiti | $1280 in Nigeria; $621 in Haiti | $172 in Nigeria; $223 in Haiti | DALY | 2008 US$ | $183; $238 |
| Shillcutt et al[37] | 2010 | Inguinal hernia repair | Ghana | $1153 | $12·88 | DALY | 2008 US$ | $13·73 |
| Warf et al[38] | 2011 | Lifetime hydrocephalus repair | Uganda | $272 | $59–126 | DALY | 2005 US$ | $69–148 |
| Shillcutt et al[39] | 2013 | Inguinal hernia repair | Ecuador | $4952 | $78·18 | DALY | 2011 US$ | $79·80 |
| **Obstetrics** | | | | | | | | |
| McCord et al[18] | 2003 | Obstetric hospital‡ | Bangladesh | $225 | $10·93 | DALY | 1995 US$ | $16·47 |
| Alkire et al[20] | 2012 | Caesarean delivery | 49 countries | $734 | $304 ($251–3462) | DALY | 2008 US$ | $324 ($268–3692) |
| **Ophthalmology** | | | | | | | | |
| Evans et al[40] | 1996 | Trachoma surgery | Burma | Data not available | $59‡ ($22–70) | HALY | 1990 US$ | $104 ($39–123) |
| Marseille et al[41] | 1996 | Cataract repair | Nepal | $155 | $5·06† | DALY | 1996 US$ | $7·40 |
| Baltussen et al[22] | 2004 | Cataract repair | Global | $876 | $54 (southeast Asia D)—$465 (Europe B)¶ | DALY | 2000 international $ | $72–620 |
| Baltussen et al[23] | 2005 | Trachoma surgery | Global | $876 | $13–17 in Africa; $36–78 in Eastern Mediterranean; $49 in the Americas; $24 in southeast Asia; $35 in Western Pacific | DALY | 2000 international $ | $17–23; $48–104; $65; $32; $47 |
| Lansingh et al[25] | 2009 | Cataract repair | Brazil; China; Ethiopia; India; Kenya; Nepal; Nigeria; Uganda Zimbabwe | $3027 in Brazil; $1251 in China; $114 in Ethiopia; $546 in India; $388 in Kenya; $245 in Nepal; $542 in Nigeria $240 Uganda $384 Zimbabwe | $60·9 in Brazil $253·6–834 China $13·8 in Ethiopia $3·7–35·1 in India $25 in Kenya $3·5–35·7 in Nepal $36·1 in Nigeria $27·9 in Uganda $55·4 in Zimbabwe | QALY | 2004 US$ | $74·0; $308·2–1013·7; $16·8; $4·5–42·7; $30·4; $4·3–43·4; $43·9 $33·9 $67·3 |
| Wittenborn et al[42] | 2011 | Glaucoma surgery | Barbados; Ghana | $9514 in Barbados; $435 in Ghana | $1272–6632 in Barbados; $1407–9808 in Ghana‖ | DALY | 2005 US$ | $1495–7797 $1654–11 530 |
| Baltussen et al[21] | 2012 | Trachoma and trichiasis surgery, cataract repair | Sub-Saharan Africa (SSA); southeast Asia (SEA) | $359 in SSA; $641 in SEA | $71–189 for trachoma in SSA; $285–849 for trachoma in SEA; $116–117 for cataract repair in SSA; $97 for cataract repair in SEA | DALY | 2005 international $ | $83–222; $335–998; $136–138; $114 |
| **Orthopaedics** | | | | | | | | |
| Gosselin et al[14] | 2011 | Orthopaedic repair | Haiti; Dominican Republic and Nicaragua | $639 in Haiti; $3160 in Dominican Republic and Nicaragua | $343 in Haiti; $362 Dominican Republic and Nicaragua | DALY | 2010 US$ | $361; $381 |
| Chen et al[12] | 2012 | Orthopaedic repair | Nicaragua | $1406 | $476·32 | DALY | 2010 US$ | $501·52 |
| **Plastic surgery** | | | | | | | | |
| Corlew et al[24] | 2010 | Cleft lip and palate repair | Nepal | $278 | $29 | DALY | 2005 US$ | $34 |
| Magee et al[43] | 2010 | Cleft lip and palate repair | Kenya; Russia; Nicaragua; Vietnam | $734 in Kenya; $10933 in Russia; $1361 in Nicaragua; $1000 in Vietnam | $96·04 in Kenya; $32·27 in Russia; $66·01 in Nicaragua; $7·36–23·83 in Vietnam | DALY | 2008 US$ | $102·41; $34·41; $70·39; $7·85–25·41 |
| Moon et al[13] | 2012 | Cleft lip and palate repair | Vietnam | $1167 | $56** ($43–65) | DALY | 2007–2010 US$ | $59 ($45–68) |

(Table 1 continues on next page)

| | Year | Intervention | Country | GDP per head* | Cost per outcome | Unit of outcome | Currency | Cost per outcome in 2012 US$ |
|---|---|---|---|---|---|---|---|---|
| (Continued from previous page) | | | | | | | | |
| **Urology††** | | | | | | | | |
| Kahn et al[44] | 2006 | Adult male circumcision | South Africa | $4882 | CER $12·10; <$0†† | DALY | 2006 US$ | $13·78 |
| Fieno et al[45] | 2008 | Adult male circumcision | Mozambique | $406 | CER $7·38; <$0†† | DALY | 2008 US$ | $7·87 |
| Binagwaho et al[46] | 2010 | Male circumcision | Rwanda | $431 | $334 for adolescents; $613 for adults | LY‡‡ | 2008 US$ | $356; $654 |
| Uthman et al[47] | 2011 | Adult male circumcision | SSA | $1142 | CER $19·71; <$0†† | DALY | 2008 US$ | $21·02 |

DALY=disability-adjusted life-year. HALY=handicap-adjusted life-year. QALY=quality-adjusted life-year. LY=life-year. *Country or regional gross domestic product (GDP) per head from World Bank in the same US$ as year of currency; calculations done on Dec 8, 2013, using 2013 index of 106.2; low-income and middle-income GDP data used for global studies—for multiple countries, we report the median value. †We report best estimates—see original study for low and high estimates. ‡Interventions include medical, obstetric or gynaecological, paediatric, and surgical care, although obstetric or gynaecological and surgical interventions constituted majority of care. §Represents reported mean of values across all phases of implementation. ¶Across all coverage scenarios, including both surgical methods; regions containing only upper-income countries excluded. ||Range represents three different case-finding models and one-time surgical laser treatment. **Represents reported mean of point values across all mission years. ††This cost-effectiveness ratio (CER) represents the incremental cost per DALY averted compared with no circumcision, wherein corresponding costs of HIV treatment are provided for HIV infections not averted by circumcision. ‡‡Outcome is LYs gained by averting HIV infection, with correction for the number of years (22 years) that would be achieved with anti-retroviral therapy. Geographical regions A–E are defined based on epidemiological similarity,[22] such that B=low adult mortality and low child mortality and D=high adult mortality and high child mortality.

***Table 1:* Studies of surgical interventions**

| | 1 | 2 | 3 | 4 | 5a | 5b | 6a | 6b | 7a | 7b | 8 | 9 | 10 | Summary score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baltussen et al (2004) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | 10 |
| Baltussen et al (2005) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | 10 |
| Binagwaho et al (2010) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | 10 |
| Baltussen et al (2012) | Y | Y | Y | Y | Y | Y | Y | Y | N/A | Y | Y | Y | Y | 10 |
| Evans et al (1996) | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | 9·5 |
| Uthman et al (2011) | Y | Y | Y | Y | Y | Y | N | Partially | Y | Y | Y | Y | Y | 9·25 |
| Marseille et al (1996) | Y | Y | Y | Y | Y | Y | Y | Y | N/A | Y | N | Y | Y | 9 |
| Warf et al (2011) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | 9 |
| Wittenborn et al (2011) | Y | Y | Y | N | Y | Y | N | Y | N/A | Y | Y | Y | Y | 8·5 |
| Shillcutt et al (2012) | Y | Y | Partially | Y | Y | Y | Y | Y | N/A | Y | N | Y | Y | 8·5 |
| Kahn et al (2006) | Y | Y | Y | N | Y | Y | N | Partially | Y | Y | Y | Y | Y | 8·25 |
| Jha et al (1998) | Y | Y | Y | Y | Y | Y | Y | Y | N/A | Y | N | N | Y | 8 |
| Lansingh et al (2009) | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | 8 |
| Shillcutt et al (2010) | Y | Y | N | Y | Y | Y | Y | Y | N/A | Y | N | Y | Y | 8 |
| Moon et al (2012) | Y | Y | N | Y | Y | Y | Y | Y | N/A | Y | N | Y | Y | 8 |
| McCord et al (2003) | Y | Y | Partially | Y | Y | Y | Y | Y | N/A | Y | N | N | Y | 7·5 |
| Gosselin et al (2008) | Y | Y | Partially | Y | Y | Y | Y | Y | N/A | Y | N | N | Y | 7·5 |
| Gosselin et al (2010) | Y | Y | Partially | Y | Y | Y | Y | Y | N/A | Y | N | N | Y | 7·5 |
| Gosselin et al (2006) | Y | Y | Partially | Y | Y | Y | Y | Partially | N/A | Y | N | N | Y | 7·25 |
| Alkire et al (2012) | Y | Y | N | N | Y | Y | Y | Y | N/A | Y | N | Y | Y | 7 |
| Chen et al (2012) | Y | Y | N | N | Y | Y | Y | Y | N/A | Y | N | Y | Y | 7 |
| Fieno et al (2008) | Y | Y | Y | Y | Y | Y | Y | Partially | N/A | N | N | N | Y | 6·75 |
| Magee et al (2010) | Y | Y | Y | N | Y | Y | N | Y | N/A | Y | N | Y | N | 6·5 |
| Debas et al (2006) | N | Y | N | Y | Y | Y | Y | N | N/A | N | N | Y | Y | 6 |
| Corlew et al (2010) | N | Y | N | N | Y | Y | Y | Y | N/A | Y | N | Y | N | 5 |
| Gosselin et al (2011) | Y | Y | Partially | N | Y | Y | N | Y | N/A | N | N | N | Y | 4·5 |

Drummond checklist questions are: 1= Was a well-defined question posed in answerable form?; 2=Was a comprehensive description of the competing alternatives given?; 3=Was the effectiveness of the programme or services established?; 4=Were all the important and relevant costs and consequences for each alternative identified?; 5a=Were costs measured accurately in appropriate physical units?; 5b=Were consequences measured accurately in appropriate physical units?; 6a=Were the cost valued credibly?; 6b=Were the consequences valued credibly?; 7b=Were costs adjusted for differential timing? 8=Was an incremental analysis of costs and consequences of alternatives done?; 9=Was allowance made for uncertainty in the estimates of costs and consequences?; 10=Did the presentation and discussion of study results include all issues of concern to users?

***Table 2:* Drummond scoring**

weighting were excluded from analysis. When different costs were provided, we excluded estimates that included consumables but did not account for infrastructure. We calculated median values for interventions for which cost-effectiveness was reported in DALYs, HALYs, or QALYs.

We extracted cost-effectiveness ratios (CERs) for non-surgical global health interventions from Disease Control Priorities for Developing Countries.[48] These values incorporate the CER with respect to the individual receiving the intervention and were derived from comprehensive literature searches to incorporate all available analyses. As such, these estimates are affected by the same variability in costing methodology as the data reported herein for surgical interventions; however, we applied the same discounting and age-weighting.

TEC and LH reviewed abstracts and TEC reviewed full articles to assess eligibility for inclusion, with disagreements resolved by discussion. TEC, KS, and MM abstracted study information and additional data to create tables and figures. TEC and KS assessed study quality using the Drummond 10-point checklist. We did iterative reviews until consensus was reached about key messages and conclusions.

### Statistical analysis

The appendix details the data extracted from each reference to generate point values and ranges for the surgical interventions identified. Quantitative synthesis was done by extracting or calculating median values for each intervention.

### Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

We identified 571 citations in our systematic review, adding an additional 14 after manual review. Of these, 26 met full inclusion criteria (figure 1). The 26 included studies[4,12–18,20–25,36–47] were published between 1996 and 2012 (table 1). The appendix and table 2 show the results of the assessment of each study with the Drummond checklist.

We extracted and converted to 2012 US$ 121 independent CERs in seven categories of surgical interventions. The most cost-effective procedures included \$7·87 per DALY for male circumcision in Mozambique,[45] and \$7·29 per DALY for cataract repair in Nepal.[25] Of the 121 interventions assessed, only five estimates exceeded \$1000 per DALY: glaucoma surgery in Barbados (\$1451·91–7570·02) and Ghana (\$1606·00–11 195·22),[42] and caesarean deliveries in Mongolia (\$1085·61), Tunisia (\$2150·88), and Libya (\$3077·56).[20] However, two of these five countries, Tunisia and Libya, are upper-middle-income countries.

The median CERs (\$ per DALY averted) for specific interventions were \$13·78 for adult male circumcisions; \$47·74 for cleft lip and palate repair; \$82·32 for general surgery, including interventions done at surgical hospitals; \$108·74 for hydrocephalus repair;[38] \$136·00 for ophthalmic surgery, including cataract, trichiasis, and trachoma surgery; \$315·12 for caesarean deliveries; and \$381·15 for orthopaedic surgery done at elective and emergency mission settings (figures 2, 3, and 4).

We also calculated CERs for adult male circumcision by comparing the cost per DALY attributed to averted HIV infections with the cost per DALY for HIV treatment in view of the higher incidence in uncircumcised men.

See Online for appendix

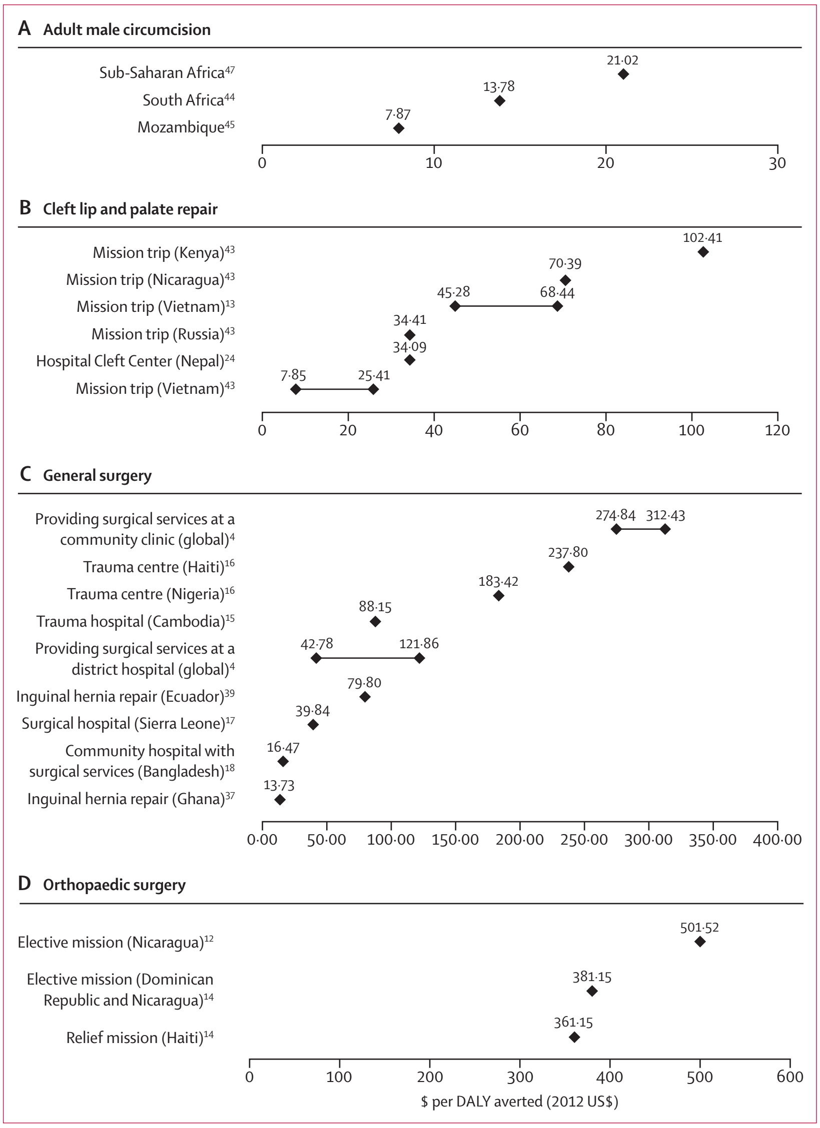


***Figure 2:*** **Cost-effectiveness ratios for adult circumcision (A), cleft lip and palate repair (B), general surgery (C), and orthopaedic surgery (D)**
DALY=disability-adjusted life-year.


***Figure 3:* Cost-effectiveness ratios for adult ophthalmic surgery**

Diamonds are DALYs, triangles are QALYs, and squares are HALYs. ICCE-AG=intra-capsular cataract extraction, using aphakic glasses. ECCE-PC-IOL=extra-capsular cataract extraction with implantation of a posterior chamber intraocular lens. Geographical regions A–E are defined based on epidemiological similarity,[22] such that A=regions with very low adult mortality and low child mortality, B=low adult mortality and low child mortality, C=high adult mortality and low child mortality, D=high adult mortality and high child mortality, and E=very high adult mortality and high child mortality.


*Figure 4:* **Cost-effectiveness ratios for caesarean deliveries**[20]

Findings from all three studies showed that provision of circumcision was cost-saving versus no circumcision, yielding a CERs of less than $0.

Figure 5 shows these values relative to traditional public health interventions. The median CERs of surgical interventions compare favourably with the selected traditional public health strategies in low-income-countries (adjusted to 2012 US$).[35,48]

## Discussion

Our findings draw attention to the cost-effectiveness of published surgical interventions, according to both international standards and in relation to traditional public health strategies. WHO has endorsed cost-effectiveness analysis to help guide policy,[49] specifically, a system based on a country's GDP per head.[50] Interventions with a CER one-to-three times greater than the host country's GDP per head are regarded as cost-effective, whereas ones with a CER lower than GDP per head are regarded as very cost-effective.[50] Table 1 shows the GDP per person of the countries included in this review and can be used to establish each intervention's cost-effectiveness based on these criteria. These values are reported in US$ in the corresponding year of the study's reported currency.[51] According to this WHO definition for cost-effectiveness, nearly all surgical interventions reported here are very cost effective. [52]

The wide range of cost-effectiveness for similar procedures shows regional variation in price, demographics, and resource use. For example, the Western Pacific region has low overall morbidity from cataracts, few cataract operations, and hence especially high programme costs per operation; therefore, the cost-effectiveness ratio of cataract surgery is less favourable here than elsewhere.[22] Estimates in this study were in international dollars, which are typically higher than estimates in US$ because of the adjustment for purchasing power parity.

The reported CERs for surgical interventions are especially interesting when compared with widely accepted public health strategies in resource-poor countries, as estimated by Jamison and colleagues.[48] Male circumcision in Africa (median CER $13·78 per DALY), cataract repair in Nepal ($7·29 per DALY),[25] and inguinal hernia repair in Ghana ($12·88 per DALY),[37] have CERs similar to WHO's Expanded Program on Immunization ($12·96–25·93 per DALY) and bednets for malaria prevention ($6·48–22·04 per DALY). Median CERs of cleft lip or palate repair ($47·74 per DALY), general surgery ($82·32 per DALY), hydrocephalus repair ($108·74 per DALY), and ophthalmic surgery ($136·00 per DALY) are all similar to that of the BCG vaccine, which costs $51·86–220·39 per DALY. We were surprised to find that the median CERs of the final two surgery categories, caesarean deliveries ($315·12 per DALY) and orthopaedic surgery ($381·15 per DALY), were the highest of the surgical categories. However, these interventions are still excellent value compared with medical treatment for chronic ischaemic heart disease ($500·41–706·54 per DALY) and HIV treatment ($453·74–648·20 per DALY) under optimum conditions. This finding is especially relevant in view of the magnitude of the disease burden that these surgical interventions address. The CERs reported for most surgical interventions studied in low-income and middle-income countries are far below these CERs for widely used interventions in these settings.

22 studies assessed particular surgical procedures and four studies assessed the overall value of surgical facilities. Our systematic search strategy, including manual review and rigorous critical appraisal, yielded an overview of a wide variety of interventions and provides a comprehensive view of the overall cost-effectiveness of global surgery.

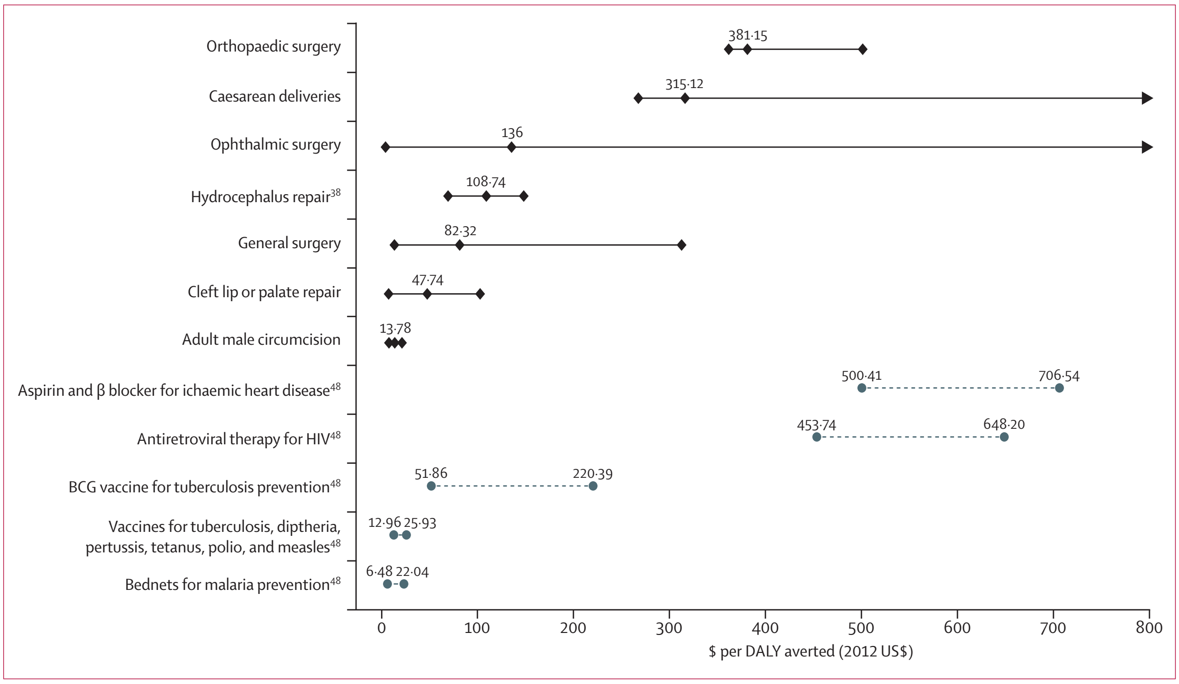


***Figure 5:* Surgery versus other public health interventions**
Datapoints are medians, error bars are range. The diamonds and solid lines are for surgical interventions; circles and dashed lines are other public health interventions.

Because no global consensus regarding modelling criteria exists, these studies use very different techniques and perspectives to assess costs and health effects. Some studies used actual cost data whereas others modelled costs on the basis of resource use assumptions. Not all studies published the breakdown of their costs and, as such, we were unable to do adjustments besides currency conversion to improve comparability. Although some studies use WHO-CHOICE[53] or other guidelines to establish costs, others have non-standardised inclusion of fixed versus variable costs, provider-level versus patient-level costs, and human labour costs. The studies that did not include fixed costs[12,14,20,43] or provider fees[14,43] have not incorporated important cost inputs into their estimates (appendix). Measurement of the efficacy and consequences of surgical intervention is not standardised, although most investigators used techniques to estimate surgical efficacy and most also used similar DALY calculation methods using Global Burden of Disease data. Variation in data quality affects the medians reported and compared with non-surgical global health interventions. However, because we reported median values, we feel that we have diminished the effect of outliers with misrepresentative costs.

Studies included here were of specific interventions in specific countries, and important differences exist in costs and effectiveness across countries. Direct comparison of costs and effectiveness across studies is difficult, although we feel we have adequately standardised the reported costs by adjusting for inflation.

Inherent bias exists in the included studies because investigators might tend to argue for the cost-effectiveness of surgery, thereby introducing a publication bias for positive studies. Moreover, the range of interventions studied included a greater proportion of low-tech, high-yield procedures (eg, cataract operations and circumcision). There might be some surgical interventions that have not yet been assessed in low-income and middle-income settings because their infrastructure demands or human-resource requirements are, correctly or incorrectly, deemed to be a barrier to efficient scale-up in the medium term. The interventions and populations in the studies included here are not exhaustive and further research would be helpful in identifying other cost-effective surgical interventions in other countries.

Findings from the Global Burden of Disease 2010 study have shown a rise in the prevalence of non-communicable diseases, which include several surgically treatable disorders.[7,32] Although the MDGs have drawn attention to key health issues in low-income and middle-income countries and have been able to generate resources for and target issues that fall within the MDG framework, those that are not included in its agenda are being left behind.[54] If left unaddressed, these disorders, which include most surgically treatable disorders, are likely to comprise more than two-thirds of the global years of life lost in 2025.[7] We therefore feel that the urgent need for surgery in global health can no longer be ignored. Additionally, our findings refute the long-held idea that surgery is not cost-effective; nearly all the studies we reviewed indicated that surgical intervention can be cost-effective or very cost-effective on the basis of WHO criteria and compared with accepted public health interventions. As the 2015 MDG target date approaches, the global health community should focus on contemporary health priorities—surgery should be included in the post-2015 MDG agenda.

Although these results show cost-effectiveness in a wide range of settings, many other arguments exist for investing in surgical capacity in addition to economic efficiency. Organisational, ethical, and political arguments can also be made for the inclusion of emergency and essential surgery as a necessary component of basic health-care packages. The Universal Declaration of Human Rights provides for health care as a basic human right,[55] and the International Covenant on Economic, Social, and Cultural Rights aims for the "highest attainable standard of physical health".[56] The provision of emergency and essential surgical interventions should be regarded as an essential human right to ensure equitable distribution of health care around the world.[57] Equitable access cannot be achieved in settings where patients are forced to incur catastrophic out-of-pocket payments for surgical services. Cost-effectiveness analysis could therefore be an important measure for policy makers to consider when deciding how to fund the delivery of surgical care.

Surgery in low-income and middle-income countries faces implementation challenges. Compared with vaccination or antiretroviral treatment, surgery needs more infrastructure—eg, clean operating rooms, anaesthesia, electrical power for monitoring equipment, and ancillary laboratory services. Although most of the cost-effectiveness analyses we reviewed did appropriately attempt to include the cost of such infrastructure, the initial infrastructure investment and the recurring cost of its maintenance might be a financial obstacle to implementation, especially when compared with less complex public health interventions. These additional costs of implementing surgical programmes should be considered when comparing CERs between surgical interventions and public health interventions.

At the same time, although surgery provision can often be categorised as a disease-specific (ie, vertical) model of health-care delivery, it also provides opportunities to strengthen long-term, infrastructure-related investments (ie, horizontal health-care delivery). So-called diagonal development is when vertical inputs ultimately increase overall access to and capacity for health systems. Some of the most notable successes in global health (including vaccination and HIV treatment) have been examples of vertical strategies that became diagonal over time. In surgery, the missions approach to cleft lip and palate repair is such an example, wherein cleft lip mission trips can strengthen health systems through the development of surgical infrastructure, training of local workforce, and provision of financial sustainability.[58]

The shortage of health-care providers in resource-poor countries is also well documented as a crucial constraint on the scale-up of surgical care[59–62] and is not typically incorporated in cost-effectiveness analyses. The restricted number of health-care providers, their training cost, and the cost of their labour will limit the number of interventions that are possible in a low-resource setting in the medium-term. Efforts to expand access to surgical interventions should therefore be tailored to the context of every country or institution. To help overcome these human resource limitations, task-shifting to non-physicians for some procedures such as caesarean delivery, trauma-related procedures, and emergency disorders has been shown to be feasible, cost-reducing, and well received by physicians in some settings.[63–67] Additional efforts are needed to assess barriers to implementation of task shifting and to support this approach where appropriate.

The high cost, infrastructure demands, and complexity of implementing surgery compared with other public health interventions are challenges, but they are not insurmountable. Our systematic review shows the high value of some surgical interventions in low-income and middle-income settings. Thus, cost-effectiveness should not be perceived as a barrier to expansion of surgery in these settings. These challenges can be addressed beginning with an emphasis on simple, high-impact surgical procedures of the sort documented in the studies we reviewed. Mock and colleagues proposed three levels of priority for surgical disorders as a road map for surgical scale-up.[11] The top priority disorders are those that have a large public health burden, for which there is a surgical procedure that is highly effective, and for which the surgical procedure (and related ancillary services and treatments) is cost effective and feasible to promote globally. Some disorders included in this category are trauma-related disorders, obstetric emergencies, hernia repairs, exploratory laparotomy for acute abdomen, and male circumcision. The data presented here suggest that cataract surgery would also be classified as a priority 1 disorder in areas with a high burden of this disease. Priority 2 disorders have a moderate public health burden, or are those for which there is a surgical procedure that is moderately successful or moderately cost-effective and feasible to promote globally. Mock and colleagues classify evacuation of intracranial haematoma, obstetric fistula repair, thyroid surgery, and mastectomy as potential examples in this category. Priority 3 surgical disorders have a low public health burden, or are those for which there is a surgical procedure that is neither highly nor moderately successful at treating the disorder, or is low in cost-effectiveness and feasibility to promote globally. These disorders might include prosthetic vascular grafts, parathyroid surgery, transplantation, and resections for pancreatic and lung cancers.

Use of this guide to scale up these types of surgical interventions, with appropriate consideration of the setting, can help to develop the necessary workforce, experience, and infrastructure and to motivate stakeholders for continued expansion to more complex surgery. Our findings show that several such surgical interventions would be priority 1 interventions. As the surgical workforce grows and the benefits of surgical intervention becomes more widely known as a component of basic health care, unit cost will decrease further with greater economies of scale and scope, and financing mechanisms can be established to enable broader access. Such improvement in economic, social, and human capital might help to mitigate shortcomings in infrastructure, allowing institutions to build surgical capacity and provide a selection of priority 2 and 3 interventions that are less cost-effective but valued for other reasons.[68]

Our findings draw attention to the heterogeneity of design in cost-effectiveness studies of surgical interventions, and show the need to standardise such research. Future studies should make every effort to adhere to existing WHO-CHOICE guidelines as well as Drummond checklists to provide comprehensive, consistent data for comparison.[10,53] Such standardisation will be especially helpful going forward, as new DALY values in the 2010 Global Burden of Disease study becomes the new standard unit of measurement in future cost-effectiveness analyses.[32]

Nonetheless, despite methodological heterogeneity, nearly all studies still showed the same result: surgical interventions are cost effective or very cost effective. The data from these studies lend support to the conclusion that a subset of surgical interventions compares very favourably to accepted health interventions in low-income and middle-income settings.

As the global burden of non-communicable diseases has increased, global surgery has begun to receive attention.[69] While the perception of surgery as an expensive intervention has been a barrier to its widespread acceptance in global health in the past, available data indicate that investment in surgical care delivery is worthwhile from an economic perspective. Although surgery requires more specialised human resources and infrastructure than many traditional public health interventions, when these challenges are met, surgery can produce health benefits with similar cost-effectiveness ratios. Findings from this study show that many surgical interventions are cost-effective to very cost-effective in resource-poor countries. When viewed in the context of a more holistic approach to health-system strengthening, surgery can play a pivotal part in population-based health-care delivery, and its ability to prevent long-term disability in a cost-effective manner shows its value in the expanding global health movement.

#### Contributors
TEC and LH did the literature review. TEC, KS, MM, and TGW designed the study. TEC, KS, and MM abstracted study information and additional data. TEC and KS assessed study quality using the Drummond 10-point checklist. TEC, KS, MM, and LH wrote the paper. All authors did iterative until consensus was reached about key messages.

#### Declaration of interests
All authors declare no competing interests.

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