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Cost-effectiveness of paediatric surgery: an economic evaluation of World Paediatric Project surgical interventions in St. Vincent and the Grenadines (2002–2019)

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ABSTRACT

Objectives The purpose of this study is to examine the cost-effectiveness of six types of surgical interventions as part of a sustained paediatric surgical programme in St.Vincent and the Grenadines from 2002 to 2019.

Design In this economic model, six paediatric surgical interventions (ophthalmic, orthopaedic, plastic, general, urology, neurosurgery) were compared with no surgery in a deterministic cost-effectiveness model. We assessed health benefits as averted disability-adjusted life-years (DALYs). Costs were included from the programme perspective and measured using standard micro-costing methods. Incremental cost-effectiveness ratios (ICERs) were calculated for each type of surgical intervention. Interventions with ICERs of <50% of gross domestic product (GDP) per capita were considered cost-effective. Costs are reported in 2019 US$. Univariate sensitivity analyses were conducted to assess the effect of uncertainty.

Results The average cost per procedure was US$16 685 (range: US$9791.78–US$72 845.76). The cumulative discounted 18-year health impact was 5815 DALYs averted with a cost per DALY averted of US$2622. Most paediatric surgical interventions were cost-effective, yielding cost per DALY estimates less than 50% of GDP per capita of St. Vincent and the Grenadines. When undiscounted, only orthopaedic surgeries had cost per DALY more than 50% GDP per capita. When considering discounting, orthopaedic and urology surgeries exceeded the adopted threshold for cost-effectiveness.

Conclusions We found that short-term, recurrent surgical interventions could yield substantial economic benefits in this limited resource setting. This research indicates that investment in paediatric surgical interventions is cost-effective for the majority of specialties. These findings are of clinical significance given the large burden of disease attributable to surgically treatable diseases. This work demonstrates that scaling up dedicated surgical programmes for children is a cost-effective and essential component to improve paediatric health.

Strengths and limitations of this study

- ► This study focuses on six paediatric surgical interventions over 18 years, providing cost-effectiveness data for each.
- ► To increase the methodological rigour and encourage the reconciliation of the differences among divergent guidelines in the field of global surgery CEAs, we employed Shrime's checklist for global surgery in the design of our study.
- ► We assumed that surgical specialties could be generalised to a single average disability weight which is a strong assumption given that overgeneralisation could result in an inaccurate representation of the spectrum of disability associated with the surgical conditions.
- ► We note that the perspective of this analysis (ie, programme) did not allow for assessing the cost-effectiveness from government or societal perspectives; accounting for issues such as affordability, budget fairness and feasibility would have provided a more comprehensive assessment.

INTRODUCTION

WHO estimates that half of the world's population lacks access to essential health services and that more than 100 million people face poverty due to medical expenses.[1] In middle-income countries (MICs), surgical interventions are critical to families, where a significant portion of family income could be absorbed by preventive and medical care.[2] Many families have little choice in where and how they seek medical treatment, leaving them unable to find less expensive care choices. Medical missions help fill this gap by providing surgical interventions through teams in a duration of 1–2 weeks. A recent study on paediatric surgical interventions in Kenya and Canada determined that surgical missions significantly lessen the disease's global burden for genetic abnormalities.[3] A similar study focusing on the impact of plastic surgery interventions in Ecuador analysed the outcomes of more than

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1000 reconstructive cases. This study concluded that surgical interventions that tackle common and treatable diseases lead to substantial clinical and economic benefits.[4] Another study based in Uganda focused on the cost-effectiveness of infrastructure improvement. They found that a dedicated paediatric operating room is cost-effective if hospital space and personnel pre-exist to staff the facility.[5] Thus, quantifying paediatric surgical missions' economic impact deserves attention from researchers and policy-makers alike. Previous studies have assessed the impact of specific paediatric surgical procedures in resource-limited settings, but existing research lacks conclusions on projects with multi-specialty scopes.[6 7] Therefore, we add to the scarce evidence related to the value of short-term, recurrent paediatric surgical missions by analysing 18 years of World Paediatric Project (WPP) paediatric surgical procedures in St. Vincent and the Grenadines. WPP is a nonprofit organisation with a mission to help critically ill children and build healthcare capacity. The scope and nature of WPP's surgical work are outlined in online supplemental material section 1. The purpose of this study is to examine the economic effect of recurrent, short-term surgical care as part of the WPP sustained paediatric surgical programme in St. Vincent and the Grenadines from 2002 to 2019. We approached the question, 'Are specialised paediatric surgical interventions cost-effective compared with no surgery?' from a programme perspective and measured by disability-adjusted life-years (DALYs). This study assessed the relevant costs and benefits of conducting paediatric plastic surgery, neurosurgery, ophthalmic surgery, general paediatric surgery, urology and paediatric orthopaedic surgery using cost-effectiveness analysis (CEA) as an analytical framework.

METHODS

Patient and public involvement statement

Patients and public representatives were not involved in the research design or analysis of this study. This study was conducted in partnership with the WPP, and results will be disseminated through the WPP website to the public.[8]

Model design

We retrospectively collected clinical data from the WPP's database comprising 914 surgical procedures for children living in St. Vincent and the Grenadines over eighteen years. Six paediatric surgical interventions (ophthalmic, orthopaedic, plastic, general, urology, neurosurgery) were compared with no surgery from a programme perspective in a deterministic cost-effectiveness model implemented in Microsoft Excel. We applied standard microcosting methods to assign procedure-level costs detailed in the online supplemental material section 2 and tables 1-3). We assessed health benefits as averted DALYs. Univariate sensitivity analyses were conducted to assess the effect of uncertainty. Costs and health outcomes data were used to estimate incremental cost-effectiveness ratios (ICERs) of conducting paediatric plastic surgery, neurosurgery, ophthalmic surgery, general paediatric surgery, urology and paediatric orthopaedic surgery. Programme costs and outputs were tabulated from services initiated between October 2002 and September 2019 in US dollars (US$), when the data set was closed. Cost-effectiveness is reported as estimates of discounted (3%) and undiscounted DALYs averted by each surgical specialty. Disability weights for paediatric specialties were obtained by averaging values from Global Burden of Disease (GBD) studies,[9] and others[3 10–13] as outlined by Saxton *et al*.[14] Calculated averages are provided in online supplemental material section 3 and table 4. The following program-level variables were selected as possible predictors of programme efficiency: personnel, management, equipment, supplies, drugs, hospital facility, surgical teams, consultations that resulted in surgery and the associated surgery provided, and children who received surgery. These predictors are outlined in online supplemental material section 2 and tables 1–3.

Clinical data

The clinical dataset on which cost estimations were generated for this study comprises 914 surgical procedures for children living in St. Vincent and the Grenadines between October 2002 and September 2019. All surgical procedures in the dataset were performed by visiting paediatric specialists in St. Vincent and the Grenadines, coordinated through WPP's International Teams Programme, and reported to WPP by completing its designated operative note form. The clinical dataset was obtained retrospectively from WPP's database and was provided in a de-identified format for the study. There are 650 paediatric patients represented in the dataset. The difference in the number of patients vs surgical procedures is due to both patients receiving more than one procedure in the same period and patients receiving procedures years apart, indicating the longitudinal aspect of WPP's clinical data. Based on WPP's criteria for qualification of paediatric specialist services for its programmes, all surgical procedures provided by a visiting surgeon to a patient were included in the dataset if the first surgical procedure that the patient received from WPP was when the patient was 0–21 years of age. Thirty-four surgical procedures were excluded from the data set. Details on the procedure exclusion criteria are outlined in online supplemental material section 4.

Estimating costs

The costs of paediatric surgical intervention include direct expenditure for medical care and indirect costs. In this study, the direct expenditures for medical care include equipment, supplies and medications purchased by WPP and an estimate of the portion of WPP's overhead, management and development costs attributable to surgeries in St. Vincent. These costs also include medical volunteers' travel to St. Vincent and the Grenadines (airfare, lodging, in-country transportation and travel

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insurance), and a portion of WPP St. Vincent staff salaries as well as the documented value of donated volunteer time, equipment, supplies and medications as reported by donor companies. Indirect costs arising from morbidity and mortality, such as time costs, are commonly included in economic evaluations.[15] In this study, we only focused on the direct costs related to the surgical intervention, as the WHO recommends excluding indirect costs from the primary analysis but including them in the secondary analysis if available.[16]

All surgical procedures considered in this study were performed free of charge to the patients. The patients also had access to necessary preoperative, postoperative and inpatient care at the same public hospital where healthcare is provided within a free healthcare system, apart from nominal fees for medications for patients over 16. Because patients are not charged for these services, no billing system tracks the actual cost of the surgical procedures that WPP directly facilitates. There is no billing system between WPP and the host hospital to enable the facility's surgical procedures. Therefore, WPP conducted comprehensive accounting of individual resources required to deliver paediatric surgical interventions and assigned each a value using standard micro-costing methods.[17] In summary, WPP estimated a total cost for each surgical procedure in the clinical dataset, representing (1) the costs incurred by WPP to facilitate the team of medical volunteers, (2) WPP's operational costs and (3) an estimate of the market value of the medical volunteers' donated services and the host hospital's facilities. Microcosting methods must be clearly described as resources that are likely to be identified and categorised in diverse ways by researchers with varying analytic perspectives.[18] Additional details on microcosting methods, including tables outlining costs, are included in online supplemental material section 2.

Estimating benefits of paediatric surgical interventions

To quantitatively measure the impact of surgical care, the outcome was calculated as DALYs averted. In the context of this research, the DALY captures the impact of paediatric surgical intervention by measuring the shortfall from a healthy life. Five DALYs, for example, can be interpreted as 5 years of healthy life lost. Therefore, paediatric surgical intervention benefits can be described in terms of the DALYs averted by the surgical procedure. Although an imperfect measure criticised for not considering contextual variables,[19] the DALY is widely promoted by the World Bank and WHO.[20 21] Selecting DALYs averted as a measure of surgical care's impact provides results comparable to other burdens of disease studies and will help determine where paediatric surgical care fits within other global health priorities.[20]

In economic analyses, the predominant argument is that it is necessary to adjust the data because we value costs and benefits differently depending on when they occur.[17] For this reason, costs and benefits are discounted using a widely accepted standard discount rate of 3%.[17] However, this argument is controversial because it may overvalue the future costs and health benefits of interventions.[22] Therefore, we present DALYs in two ways: (1) DALYs without discounting and (2) DALYs with discounting. In both cases, we applied no age weighting. Disability weights are critical to the DALY calculation because a weighting factor is applied that reflects the severity of a disease on a scale from zero (perfect health) to one (death). Due to many surgical conditions and interventions, assigning disability weights and surgical care values is challenging.[20] Also, the impairment associated with each condition depends on social and cultural variables.[20] Ideally, disability weights specific to St. Vincent and the Grenadines, as well as WPP programmes, would be available. Given that these are unavailable, we adopted an alternative approach to calculating disability weights by taking a simple average for each specialty across multiple procedures. Disability weights for paediatric specialties were obtained by averaging values from GBD studies[10 23] and others,[3 11–13] as outlined by Saxton *et al*.[14] Average disability weights for paediatric surgical specialties ranged from 0.076 for orthopaedics to 0.562 for neurosurgery. The DALY calculation is provided in online supplemental material section 5. Developing a more rigorous methodological approach that uses the average value for disability weights and the value of surgical care could facilitate a more detailed analysis of surgical services.[20] At a minimum, further research could use a weighted average that considers the percentage of the total within each class of surgery associated with each of these procedures. This would require information on the percentage distribution of procedure type within each specialty unavailable in our data set.

Estimating cost-effectiveness

We divided the total costs by the total DALYs averted (discounted or undiscounted, respectively) to determine each surgical specialty's ICER. We also present the ICER for all interventions together. To determine whether the surgical intervention is cost-effective, the ICER is assessed against a general value. A commonly employed threshold to gauge the magnitude of the monetary estimates presented compares ICERs to 1–3 times gross domestic product (GDP) per capita.[16 24] In resource-constrained settings, this approach has significant shortcomings, including obscuring meaningful comparisons, easy attainment of thresholds, a reliance on untested assumptions, and inadequate appraisal of affordability.[25] Therefore, we adopted a more recent approach to determining cost-effectiveness by considering interventions with ICERs of <50% of St.Vincent and the Grenadines 2019 (GDP per capita; 0.5×US$7457.24=US$3736.91) to be cost-effective rather than the 1–3 GDP rule.[26 27] The use of half GDP per capita to estimate the cost-effectiveness has appeared in a paper assessing the cost-effectiveness of diagnostic HIV infection in South Africa.[28] In addition, the half of GDP per capita approach was referenced in the Disease Control Priorities three as an example in resource-limited settings.[29]

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Table 1 Descriptive statistics of procedures

Characteristics		
No of procedures	914	
Mean age in years	7.94	
Age yrs (range)	0–24.25	
	Count	**Percentage**
Female	434	48
Male	470	51
Unknown	10	1
Medical specialty		
Plastic surgery	193	21
Neurosurgery	46	5
Ophthalmic surgery	255	28
Ped general surgery	141	15
Urology	54	6
Orthopaedic	225	25

RESULTS

Procedures

Of the 914 procedures (table 1), 48% were performed on females and 51% on males. The average age of patients during procedures was 7.94 years, with an SD of 5.96. The youngest recorded patient was less than 1 month at the time of their procedure, and the oldest was 24.25 years. WPP performed 46 neurosurgery procedures, 255 ophthalmology procedures, 225 orthopaedic surgeries, 141 general paediatric surgeries, 193 plastic surgeries and 54 urology procedures. Common procedures included strabismus correction, hydrocephalus shunting, hernia repair, spinal fusion and cleft palate repair.

Costs

Results are presented in 2019 US dollars (US$). The total cost of all 914 procedures conducted by the WPP in St. Vincent and the Grenadines was US$15 250 189.97, with an average cost per procedure of US$16 685 (table 2).

Table 2 Cost distribution (USUS$)

Characteristics	Value	Mean
No of procedures	914	
Total cost (US$)	US$15 250 189.97	16 685
Range (US$) (min-max)	US$9791.78–US$72 845.76	
Total gifts in kind (US$)	US$11 370 965.82	
Cost per medical specialty (US$)		
Neurosurgery	US$1 059 737.84	23 037.78
Ophthalmology	US$3 035 583.29	11 904.25
Orthopaedic	US$5 376 974.24	23 897.66
Ped general	US$2 287 408.19	16 222.75
Plastic surgery	US$2 673 862.54	13 854.21
Urology	US$16 623.87	15 122.66

Table 3 Estimates of averted DALYs

Surgical intervention	Total cases	DALYs (undiscounted)	DALYs (discounted)
Ophthalmic surgery	255	4818	1817
Orthopaedic	225	1374	544
Plastic surgery	193	2778	1075
Ped general surgery	141	4079	1544
Urology	54	272	106
Neurosurgery	46	1979	729
Total	914	15 300	5815

DALYs, disability-adjusted life years.

The lowest cost for a procedure was US$9791.78, with the highest being US$72 845.76. By total cost, the most expensive medical specialty was orthopaedic surgeries, which consisted of 35.3% (US$5 376 974.24) of the total cost for all the procedures. An orthopaedic procedure's average cost was US$23 897.66; these procedures were used to help relieve diagnoses of clubfeet, scoliosis and various other orthopaedic conditions. The medical specialty with the highest average cost per procedure was neurosurgery; however, this discipline saw the second-lowest total cost and the lowest number of procedures.

Estimated effects: DALYs averted

Table 3 provides estimates of discounted (3%) and undiscounted DALYs averted by each surgical specialty. There were 5815 total discounted DALYs averted by the six programmes. The top three (with 3% discounting) were ophthalmic surgery (US$1817), general paediatric surgery (US$1544) and plastic surgery (US$1075). Table 3 further shows that the surgical interventions together led to US$15 300 undiscounted DALYs averted, with ophthalmic surgery averting the most DALYs and urology averting the least.

Cost-effectiveness of paediatric surgeries

Table 4 presents the ICERs for each surgical specialty and all specialties together, with or without discounting both costs and DALYs. All financial data were standardised to 2019 using the World Bank's consumer price index conversion factors.[27] The undiscounted cost per DALY averted ranged from approximately US$551 for neurosurgery to US$4031 for orthopaedic surgery. The cost per DALY averted with discounting ranged from US$1453 for neurosurgery to US$9892 for orthopaedic surgery. Together, the cost per DALY averted is US$1027 without discounting and US$2622 with discounting. Most of the paediatric surgical conditions assessed are cost-effective with and without discounting, yielding cost per DALY estimates that are less than <50% of St.Vincent and the Grenadines 2019 GDP 2019 GDP per capita—only undiscounted orthopaedic surgeries had cost per DALY of more than 50% GDP per capita. With discounting,

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Table 4 Incremental cost-effectiveness ratios

Specialty	Undiscounted Total cost (2019 USD)	Undiscounted DALY	Undiscounted Cost per DALY averted	Discounted Total cost (2019 USD)	Discounted DALY	Discounted Cost per DALY averted
Cranofacial/plastic surgery	2 754 078.42	2778.00	991.39	2 673 862.54	1074.73	2487.94
Neurosurgery	1 091 529.97	1979.00	551.56	1 059 737.84	729.29	1453.10
Opthalmic surgery	3 126 650.79	4818.00	648.95	3 035 583.29	1817.20	1670.47
Ped general surgery	2 356 030.44	4079.00	577.60	2 287 408.19	1544.00	1481.48
Urology	841 122.59	272.00	3092.36	816623.87	106.46	7670.64
Orthopaedic	5 538 283.47	1374.00	4030.77	5,376,974.24	543.58	9891.77
All cases	15 707 695.67	15 300.00	1026.65	15 250 189.97	5815.27	2622.44

DALYs, disability-adjusted life-years.

urology and orthopaedic surgeries exceeded the cost-effectiveness threshold.

Interventions with ICERs of <50% of St.Vincent and the Grenadines 2019 (GDP per capita; 0.5×US$7473.83=US$3736.91) were considered to be cost-effective

Sensitivity analysis

The base case ICER for the various paediatric surgical interventions were US$1453.10 for neurosurgery; US$1670.47 for ophthalmic surgery; US$9891.77 for orthopaedic surgery; US$1481.48 for general paediatric surgery; US$2487.94 for plastic surgery and US$7670.64 for urological surgery. A one-way sensitivity analysis was conducted to address uncertainty. The ICER variations are summarised as a table and tornado diagrams in online supplemental material section 6, table 5 and figures 6.1-6.6. The ICER's most influential drivers are the lower-bound disability weights in paediatric surgeries and discounting at 5% with no age weighting.

Building on local infrastructure

WPP coordinates paediatric surgical missions to St. Vincent and the Grenadines because the country's population is too small to generate the caseload necessary to attract and retain dedicated paediatric specialised surgeons. While partnering with the Ministry of Health to administer a surgical fellowship is beyond the scope of WPP's mission, the organisation does partner with local surgeons to provide equipment and operate in emergencies when paediatric specialists are not available. WPP teams also invite surgeons from other Eastern Caribbean regions to take part in surgical missions. Recognising the limitations of developing genuinely sustainable local paediatric surgical practices in small-population settings, the WPP model has evolved to serve as a critical complement to the local healthcare system's surgical services, with the surgical training and development for local providers as an additional targeted benefit provided to the country.

DISCUSSION

According to the World Bank, St. Vincent and the Grenadines moved from a lower-MIC to upper-MIC in 2003.[30] However, given very small population sizes and geographical isolation, these Eastern Caribbean countries are incredibly resource-constrained from the standpoint of health resources, even if the national Gross national income (GNI) reflects a higher classification. For example, St. Vincent and the Grenadines lacks advanced diagnostic imaging, paediatric surgical subspecialists, and paediatric intensive care, all of which one would expect to see in a non-resource constrained health system. This analysis establishes the cost-effectiveness of most WPP surgical interventions in St. Vincent and the Grenadines compared with no surgical intervention. The results demonstrate that short-term, recurrent paediatric surgical interventions can yield substantial economic benefits in this limited resource setting. Other studies have found that paediatric surgical interventions are highly cost-effective in other resource-constrained settings, including Africa, Asia, Latin America and the Caribbean.[3 11 14 21 31–33] However, like Hughes *et al* our study focuses on the cost-effectiveness of surgeries undertaken by charitable organisations.[4] A recent systematic review of charitable surgical platforms found that short-term temporary surgical missions should be limited to areas and conditions for which no other surgical delivery platform is available.[34] Our results indicate that WPP generates economic benefits that outweigh the programme and other costs associated with such interventions in St. Vincent and the Grenadines. In the case of WPP, surgical teams that deliver the interventions are mainly based in the US. The costs associated with such teams could be relatively higher than for teams based at the location of interventions. That could explain the somewhat higher ICER in our study, compared with those from other studies elsewhere of under approximately US$2020 (2015 US$) per DALY averted for 29 studies reported in Saxton.[14] In order to determine cost-effectiveness, our ICERs were evaluated against a predefined decision rule. We adopted half of GDP per capita as a rule of thumb to estimate

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the cost-effectiveness based on significant shortcomings in the 1–3 GDP per capita approach.[25 26] According to recent research by Ochalek, applying a 3× GDP per capita approach to assess the cost-effectiveness of interventions results in an underestimate of health opportunity costs for 100% of upper-MICs such as St.Vincent and the Grenadines, and 1× GDP per capita underestimates health opportunity costs for 87% for these countries. Adoption of a 1–3 GDP per capita approach can result in decisions that, according to Ochalek, 'displaces more health than (the interventions) generate.'[35] Using a 0.5× GDP per capita approach minimises this bias and more accurately reflects health opportunity costs in that these costs are only underestimated in 31% of upper-MICs.[35] That notwithstanding, majority of the ICERs in St. Vincent and the Grenadines still represent good value for money, even after accounting for changes in disability weights and discount rates.

There are vast disparities in the methodology used to establish the cost-effectiveness of global surgery.[15 36] To increase the methodologic rigour and to encourage the reconciliation of the differences among divergent guidelines in the field of global surgery CEAs, we employed Shrime's checklist for global surgery in the design of our study (online supplemental material section 7 and table 6).[15] Of course, there are limitations to this type of research, including dependence on a range of assumptions. It is essential to denote the assumptions under which the primary analysis was performed. We assumed that every child who received surgery was cured without complications. This assumption was based on the observed rates of complications in the past 5 years. A frequent criticism of medical mission trips is the lack of follow-up that occurs post-operatively, as the travelling surgeons leave shortly after their cases and cannot follow these patients long-term to take care of complications. WPP has prioritised ongoing programme monitoring and evaluation as a key component of programme operations by using a custom-designed database to track all patients up to the age of 21. This database is also a key reporting source for ongoing programme monitoring and quality improvement, disease trend analysis and strategic decision making about new programme development. This quantitative data are coupled with qualitative information acquired through surveys, questionnaires, and ongoing dialogue with patients, partners and other stakeholders. Patient follow-up is generally managed through existing relationships with paediatricians or specialists.

In most cases, referrals come from the patients' physicians, and those practitioners generally manage immediate postoperative follow-up care. In-country staff also follow-up on postoperative imaging/lab requests and ongoing consultation with WPP treating physician regarding patient follow-up and any specific issues that arise throughout the year. WPP volunteers also provide telehealth services to ensure adequate follow-up and positive outcomes. Longer term, many patients will return for consultation with WPP volunteer physicians during future surgical missions or be referred to advanced care in the US. In nearly all cases, WPP is aware of a patient's death. In most cases of serious postoperative complications, WPP is also aware. This assumption was based on the observed rates of complications in the past 5 years. A significant limitation to highlight is the selection of disability weights used in this analysis. We assumed that surgical specialties could be generalised to a single average disability weight which is a strong assumption given that overgeneralisation could result in an inaccurate representation of the spectrum of disability associated with the surgical conditions. This approach does alleviate some methodological limitations by providing consistency in categorisation by surgical specialty; it is not a perfect solution. Ideally, disability weights specific to St. Vincent and the Grenadines, as well as WPP programmes, would be available.

Given that these are unavailable, we adopted an alternative approach to calculating disability weights by taking a simple average for each specialty across multiple procedures. The references for disability weights are provided in online supplemental material section 8. At a minimum, further research could use a weighted average that considers the percentage of the total within each class of surgery associated with each of these procedures. This would require information on the percentage distribution of procedure type within each specialty unavailable in our data set. To explore how sensitive our ICERs are to the choice of disability weights, we varied the weights (using minimum and maximum for the categories) in the sensitivity analysis. Finally, we assumed that patients are de facto travelling to the US to get surgery under US surgical costs. Calculating paediatric surgical interventions' costs requires that information be available on all significant direct expenditures and indirect costs. No such comprehensive data are available. We attempt to derive a roughly comparable cost to what similar services would cost in the US. More rigorous, detail-informed methodologies are warranted, therefore, cost estimates should be viewed as a starting point for the sensitivity analysis. The WPP used a microcosting framework led by a physician experienced in the healthcare revenue cycle to obtain the best possible cost data. The team measured this data's credibility using procedure documentation from surgical teams and facilities and consulted with medical practices to validate these estimates against averages of the physician and hospital systems reported values of services provided. Most of the potential variation in costs comes from the estimates of our medical volunteers' donated services which were self-reported and may bias the results by being overestimated.

Next, we focus on the limitations of the methodological approach; this analysis may underestimate paediatric surgical intervention benefits since the CEA's analytical structure is only designed to reflect the DALY. A DALY-based approach estimates future disability diverted after a surgical intervention but fails to capture the years lived with an untreated disability before the intervention occurred.[37] Finally, we note that this analysis's perspective (ie, programme) did not allow for assessing the

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cost-effectiveness from government or societal perspectives, though accounting for issues such as affordability, budget fairness, and feasibility would have provided a more comprehensive assessment.[38]

In conclusion, we reviewed the data and calculated the averted DALYs and cost-effectiveness for paediatric surgical procedures performed by WPP. We found that short-term, recurrent surgical interventions can yield substantial economic benefits in this limited resource setting. Results indicate that large health gains have been achieved, by alleviating the health burden that faces the patients WPP treats, in interventions that represent good value for money. These results support the need to scale up surgical services for children as an essential component of addressing the total GBD.

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Supplemental Material

Belonging to the manuscript:

The cost-effectiveness of pediatric surgery: an economic evaluation of World Pediatric Project surgical interventions in St. Vincent and the Grenadines (2002-2019)

Dolan CB, *et al. BMJ Open* 2021; 11:e050286. doi: 10.1136/bmjopen-2021-050286

Contents

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1. Scope and nature of World Pediatric Project's surgical work

WPP is a nonprofit organization with a mission to help critically ill children and build health care capacity globally. WPP links access to care for children with often highly complex or urgent surgical intervention situations to the medical community through a combined approach of both direct care and capacity-building programs. The WPP program model includes mobilizing visiting surgical and diagnostic teams, coordinating surgical care for complex cases at advanced U.S. or regional hospitals, and training and supporting medical providers caring for critically ill newborns. The organization's program reaches currently focuses on Central America and the Caribbean. As one of its most established programs, the organization has coordinated short-term multidisciplinary surgical teams in St. Vincent and the Grenadines since 2002. WPP's surgical work scope and nature in St. Vincent provide context on surgical missions' economic impact, which has yet to be thoroughly discussed in the academic literature.

2. Costs of surgical intervention

The costs of surgical intervention include direct expenditure for medical care and indirect costs. In this study, we only focused on the direct costs related to the surgical intervention. The WHO recommends excluding indirect costs from the primary analysis but including them in the secondary analysis if available.[1] Our micro-costing was conducted from a program perspective and used 2019 $USD. The clinical dataset upon which cost estimations were generated for this study comprises 914 surgical procedures for children living in St. Vincent and the Grenadines between October 2002 and September 2019. WPP estimated a total cost for each surgical procedure in the clinical dataset, representing 1) the costs incurred by WPP to facilitate the team of medical volunteers, 2) WPP's operational costs, and 3) an estimate of the market value of the medical volunteers' donated services and the host hospital's facilities. The developed micro-costing framework outlined below applied standard micro-costing methods of cost gathering.[2,3] Each cost element (e.g., equipment, supplies, medications, travel, staff salaries) was labeled individually and given its own unit cost. These costs were then summed to give subtotals for each category of cost by procedure type. Finally, the subtotals were then summed to calculate the total cost for the whole program. The included costs are outlined in Tables 1-3. A detailed description of these costs is provided in Tables 1-3.

Table 1: WPP's financial implementation costs and the estimated value of service

Variable and definition	Cash Expenditures	In-Kind Estimates
Personnel – WPP medical volunteers, participating in visiting surgical teams* to St. Vincent	All mission line items for WPP budget except supplies and shipping (see below) Ex. Airfare, lodging, transportation, travel insurance, etc.	The gift in kind calculation for the value of surgical services**, and hourly calculations for non-physician medical volunteers, as well as travel; calculated per surgical service
Management – WPP's staff and overhead costs associated with implementing surgical mission teams* to St. Vincent	Staff salaries for the trip coordinator and international representative, overhead costs	SEE SECTION CALLED ESTIMATED COSTS INCURRED BY HOST HOSPITAL
Equipment – tools that WPP purchases/acquire to perform surgery in St. Vincent	Any costs paid directly by WPP for tools	Dollar figures reported by companies to WPP for the value of donated tools
Supplies – disposable materials and implants/hardware required to perform surgery in St. Vincent	Any costs paid directly by WPP for supplies; shipping costs for supplies	Dollar figures reported by companies to WPP for the value of donated supplies and hardware
Drugs – medications that WPP purchases/acquire to perform surgery in St. Vincent	Any costs paid directly by WPP for medications	Dollar figures reported by companies to WPP for the value of donated medications

Table 2: Estimated costs incurred by Vincentian host hospital

Variable and definition	Cash Expenditures	In-Kind Estimates
Hospital facility – to include clinic and OR space, inpatient stay, imaging, and lab services, prescriptions	Not known	Gift in kind calculation made by WPP that attempts to estimate the contribution of the host hospital per procedure provided through the visiting WPP team

Table 3: Inclusion/exclusion criteria for calculated costs for variables in tables 1 and 2

For each of the variables above, WPP will include/exclude data for:	Included:	Excluded:
***VISITING SURGICAL TEAMS**	WPP visiting teams to St. Vincent that traveled to provide surgical services	Diagnostic only WPP visiting teams to St. Vincent
****SURGICAL SERVICES**	Consultations that result in a surgery and the associated surgery(es) provided	Consultations that do not result in surgery
CHILDREN	Children from St. Vincent who received surgery from a WPP visiting surgical team to St. Vincent	Children from other islands in the E.C. region receiving surgery from a WPP visiting team to St. Vincent

A detailed explanation of WPP's method for cost calculation for the variables in tables 1 and 2:

A dollar value for each variable in tables 1 and 2 have been calculated for each procedure provided in the clinical dataset and listed by variable on the same row as the procedure's clinical data. The following explains how each variable was calculated.

WPP's calculation of in-kind gift values for personnel and host hospital facility variables

In 2018, WPP developed an in-kind calculation system to account for the value of medical services provided by traveling medical teams. The system's formation was guided by WPP's Board of Directors and vetted by WPP's external auditors. The system is composed of the following as WPP's standard method for calculating the value of any international team's services to a given group of children for the below-listed variables in this evaluation:

Table 1: Personnel variable

For surgeons, a dollar value for each surgery provided during a team's travel that is determined by the following:

- Surgeon's medical specialty (neurosurgery, ophthalmology, orthopedic surgery, etc.)
- Coding of the surgeon's procedure provided as either simple or complex, if applicable for the surgeon's medical specialty:
  - This applies to the following medical specialties: general surgery, neurosurgery, orthopedic surgery (lower extremity), plastic surgery, and urology *(Medical specialties in the WPP network for which this does <u>not</u> apply are audiology; ENT; cardiac catheterization, electrophysiology, or open-heart surgery; intervention for clubfoot; craniofacial surgery; ophthalmology; orthotics provision; spine surgery; and upper extremity surgery).*
  - Complex procedures carry a higher estimated dollar value than simple procedures. Rates vary between surgical subspecialties.
  - WPP laypeople perform determination of complex procedures. See criteria established by WPP staff for determining complex procedures for this study in the following explanation called "Criteria for Coding Complex Procedures."*

- For surgeons, a standard rate is applied to each consultation given on clinic day. This is a standard rate based on the volunteer's role as a surgeon and not based on medical specialty.

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- For anesthesiologists, a dollar value for each surgery provided during a team's travel that is determined by a rate per medical specialty
- For anesthesiologists, an hourly value of service for clinic days when consultations are provided. This is a standard rate based on the volunteer's role as an anesthesiologist and not based on medical specialty.
- For all other medical volunteers traveling with the team, a daily value of service is calculated for each working day of the team's travel. The value is calculated by an hourly rate assuming 8 hours worked on each working day. The hourly rate is determined by the specific volunteer's role with the medical team (registered nurse, nurse anesthetist, OR tech, therapist, etc.) and not based on medical specialty.
- For all medical volunteers working with a medical team, a value is calculated for each volunteer's travel time to account for time away from his regular work. The hourly rate established for the volunteer's role with the medical team is multiplied by an assumed 16 hours of travel with the medical team, based on the assumption of two 8-hour days of travel per trip

Cash expenditures for personnel

We have calculated a per-procedure measure of WPP's direct costs for mobilizing WPP medical teams by adding all the cash expenditures for a given mission (except for supply purchases/shipping) and multiplying this sum by the portion of the mission's per-case gift-in-kind (i.e., from surgeon fee, complex surcharge, consult fee, anesthesia fee) attributed to that procedure.

Table 1: Management

WPP's accountant calculated program, administration, and development costs for FY 18/19 and estimated the portion attributable to St Vincent missions for a total of 15%. This estimate was made based on the portion of program personnel dedicated to international teams and the share of mission teams traveling to St Vincent. We then estimated the relative value of surgical patient care to consultation-only care using 2019 gift-in kind calculations for a surgical fee and calculated that 93% of mission costs are attributable to surgical patients (as opposed to patients only receiving a consultation. The resulting amounts were divided evenly among the 189 surgeries performed in St Vincent that year to develop a per-case figure for these expenses. It was not practical to perform this analysis on a historical basis. Since our current cost structure is of most interest to us in assessing our program, we applied these values retroactively to past procedures.

Table 1: Equipment, supplies, and drugs variables

The value of donated supplies and equipment and the cash expenditures on these items are tracked for each surgical mission. The per-case value of donated equipment/supplies and cash expenditures on these items are calculated by dividing total expenditures/donations for that mission and dividing by the number of surgical cases. In some cases, we do not have estimates for the value of donated supplies/equipment, generally because the supplier did not provide these or because donations were acquired by a third party, such as a WPP medical volunteer.

Table 2: Hospital Facility

- A dollar value for the use of the host hospital's clinic space for conducting consultations during a WPP medical team's visit is determined through WPP identifying the hospital as a level 1 (most comparable to U.S. hospital resources), 2, or 3 (least comparable to U.S. hospital resources) and utilizing the associated per-consultation fee to calculate the value of the host hospital resources used by multiplying it by the number of consultations given by surgeons on the team's clinic day. The level assigned to the host hospital for all procedure data in this dataset is level 2.

- A dollar value for using the host hospital's operating room and associated resources during a medical team's visit is calculated on a per-procedure basis. The dollar value used per procedure provided is based on the hospital's level determined by WPP and the medical specialty of the procedure provided.

Criteria for Coding Complex Procedures

- For this study, WPP staff excluded any procedures from the complex category if they are listed as essential pediatric surgical procedures that are cost-effective and can be provided at a first-level hospital by Disease Control Priorities. Usually, WPP staff would take a less conservative approach in coding and identify some of these procedures as complex when deemed applicable. However, we thought it essential to have as strong a criteria as possible for coding complex procedures for this study.
- The following types of procedures were deemed complex for this study because they were not a part of the list of essential surgical procedures delineated by Disease Control Priorities or were decided by WPP staff to be more complex than other surgical procedures provided in the same specialty by WPP medical teams:
    - General surgery:
        - Repair of jejunal atresia
        - Laparoscopic cholecystectomy
        - Repair of gastroschisis
        - Repair of duodenal stenosis

    - Nephrectomy
    - Laparoscopic splenectomy
    - Nissen fundoplication
    - Laparoscopic Malone procedure
    - Kasai procedure for biliary atresia
    - Repair of esophageal atresia
  - Urology:
    - Hypospadias primary repair and subsequent revisions
    - Epispadias
    - Pyeloplasty
    - Ureteroureterostomy
    - Correction of penile curvature
    - Hydrocelectomy
    - Uretal reimplantation
    - Cyst incision posterior urethral valves and vesicostomy closure
  - Orthopedic surgery:
    - Scoliosis surgery
    - Epiphysiodesis
    - Hemiepiphysiodesis
    - Syndactyly release
    - Osteotomies not associated with clubfoot diagnosis
    - Release for Erb's palsy, elbow contractures

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    - Any surgical treatment of SCFE, LLD, and Blount's disease (genu varum) except for hardware removal
    - Surgical treatment of cerebral palsy that is not hamstring lengthening, tendon Achilles lengthening, tenotomy, or soft tissue releases
    - Surgery for hip adduction contractures/dislocation
    - Wrist fusion
    - Ankle fusion
  - Neurosurgery:
    - Release of tethered cord
    - MMC repair (spina bifida)
    - Resection/removal of encephalocele (occipital)
    - Cranioplasty/elevation of depressed skull fracture
    - Other spine surgery
    - Lipoma resection
  - Plastic surgery:
    - Reconstruction for microtia/other congenital ear defects
    - Syndactyly/polysyndactyly repair
    - Clitoroplasty

3. Disability weights utilized in cost-effectiveness analysis

Table 4. Disability weights for pediatric specialties outlined by Saxon[4]

INTERVENTION	WEIGHTS
General Surgery	
Appendectomy[5]	0.158
Buruli ulcer[6]	0.051
choledochal cyst excision[6]	0.114

Table 4. Disability weights for pediatric specialties outlined by Saxon[4]

cystic echinococcosis[7]	0.239
Drainage of iliopsoas abscess[6]	0.114
Hirschsprung's repair: transanal endorectal pull-through[8]	0.720
Inguinal hernia repair[9]	0.300
Kidney Transplantation[6]	0.547
Liver Transplantation[5]	0.330
posterior sagittal anorectoplasty[5]	0.850
removal of ureteral stents[5]	0.067
Splenectomy[6]	0.114
Average	***0.300***
Orthopedics	
Amputation: arm[6]	0.079
amputation: thumb[6]	0.011
amputation: Finger[6]	0.005
Femoral shaft Fractures[6]	0.042
Musculoskeletal injuries[6]	0.079
Open tibial injuries[6]	0.055
Pediatric trauma: major surgical treatment[5]	0.208
Pediatric trauma: minor procedures[6]	0.014
Ponseti clubfoot management[10]	0.231
Various orthopedic Injury procedures[6]	0.042
Average	***0.0766***
Urology	
Genital Reconstruction[6]	0.114
Average	***0.114***
Ophthalmology	
Cataract repair[6]	0.031
Corneal ulcers[6]	0.031
Laser treatment for retinopathy of prematurity[6]	0.184
Ocular trauma[5]	0.354
Trachoma: Blindness[5]	0.570
Trachoma: Low vision[5]	0.170
Average	***0.223***
Neurosurgery	
Epilepsy: anterior temporal lobe lobectomy	0.552
epilepsy : corpus callosotomy[6]	0.552
Frontoethmodial meningoencephalocoele[6]	0.405
Hydrocephalus[8]	0.740
Average	***0.562***
Plastic and Reconstructive Surgery	
Burns: superficial[6]	0.016
Burns: partial thickness[6]	0.314
Burns: full thickness[6]	0.314

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Table 4. Disability weights for pediatric specialties outlined by Saxon[4]

Cleft lip[5]	0.082
Cleft Palate[5]	0.216
Average	***0.188***

4. Procedure exclusion criteria

The following criteria resulted in the exclusion of surgical procedures from the dataset: that a surgical procedure was provided to a patient over the age of 21 years at the time of the procedure with no previous surgical procedures documented for the patient with the program; that the description of diagnosis and surgical procedure were not available or were incomplete; or that data was erroneously labeled as a surgical procedure in WPP's database. Based on these criteria, 34 surgical procedures were excluded from the dataset.

5.Calculation of outcome (DALY)

DALY=(YLL + YLD)

The YLL is the mortality component of the DALYs and is calculated as:

YLL= (number of deaths X life expectancy at the age of death which was 73 years in 2019)

In this research, we use the life expectancy at the age of death from the Global Burden of Disease life table; that table has a life expectancy at birth of 86 for both males and females.

The YLDs are the morbidity component of the DALYSs and are calculated as:

YLD=(number of cases X duration until remission or death X disability weights)

6. Sensitivity analysis

The base case incremental cost-effectiveness ratios (ICER) for the various pediatric surgical interventions were $1,453.10 for neurosurgery; $1,670.47 for ophthalmic surgery; $9,891.77 for orthopedic surgery; $1,481.48 for pediatric general surgery; $2,487.94 for plastic surgery; and $7,670.64 for urological surgery. A one-way sensitivity analysis was conducted to address

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uncertainty, and the results on the variations of ICER are summarized in Table 5 and as a tornado diagram in Figures 6.1-6.6. In these figures, the x-axis is the USD per DALYs averted. The base values of the tornado graph are indicated on the left, which corresponds to all inputs set at their "base" settings, i.e., with no sensitivities incorporated and not as a vertical line on the x-axis. Different inputs were varied (represented by a separate bar) to determine the overall effect on the DALYs averted, as shown on the right side of the figure. Typically, we choose a "low" and a "high" value for each input. The base-case value in the figures is between the lower and upper bounds. The ICER's most influential drivers are the lower-bound disability weights in pediatric surgeries and discounting at 5% with no age weighting.

Table 5: Sensitivity Analysis

Parameters	Change	Cost per DALY					
		Ophthalmic surgery	Neurosurgery	Plastic surgery	Orthopedic	Pediatric general surgery	Urology
Base estimates	Base case scenario	1,670.47	1,453.10	2,487.94	9,891.77	1,481.48	7,670.64
Discount rate	Increasing discount rate from 0% to 5% without age weighting	2,579.51	2,256.02	3,817.88	15,105.67	2,284.70	11,745.54
	Increasing discount rate from 0% to 3% with age weighting	1,395.53	1,246.25	2,055.51	8,003.93	1,249.96	6,359.61
	No discount; no age weighting (k=0)	630.09	535.49	962.47	3,913.86	560.85	3,005.21
	No discount; full age weighting (k=1)	591.95	505.73	906.67	3,665.22	530.68	2,763.52
Disability weight:	Increasing the disability weight from 0.223 to 0.570	675.20					
	Decreasing the disability weight from 0.223 to 0.031	9,168.38					

Table 5: Sensitivity Analysis

	Increasing the disability weight from 0.562 to 0.740	1,187.86				
	Decreasing the disability weight from 0.562 to 0.405	1,810.82				
	Increasing the disability weight from 0.188 to 0.850		1,492.77			
	Decreasing the disability weight from 0.188 to 0.051		29,295.52			
	Increasing the disability weight from 0.077 to 0.231			3,404.65		
	Decreasing the disability weight from 0.077 to 0.005			84,964.93		
	Increasing the disability weight from 0.300 to 0.850				592.14	
	Decreasing the disability weight from 0.300 to 0.051				4,648.27	
	Increasing the disability weight from 0.071 to 0.114					5,334.65
	Decreasing the disability weight from 0.071 to 0.028					13,646.14

Figure 6.1: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Ophthalmic surgery*

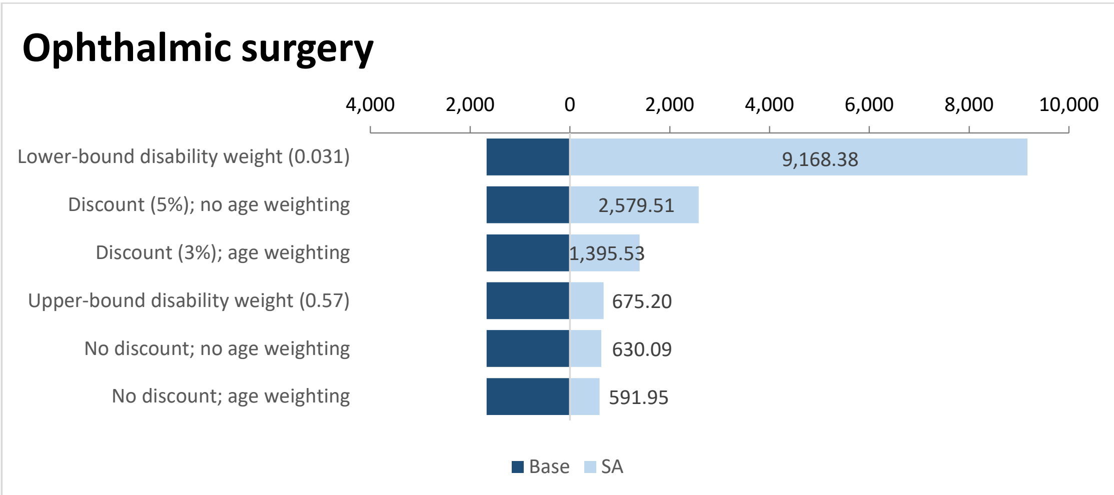

Figure 6.2: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Neurosurgery surgery*

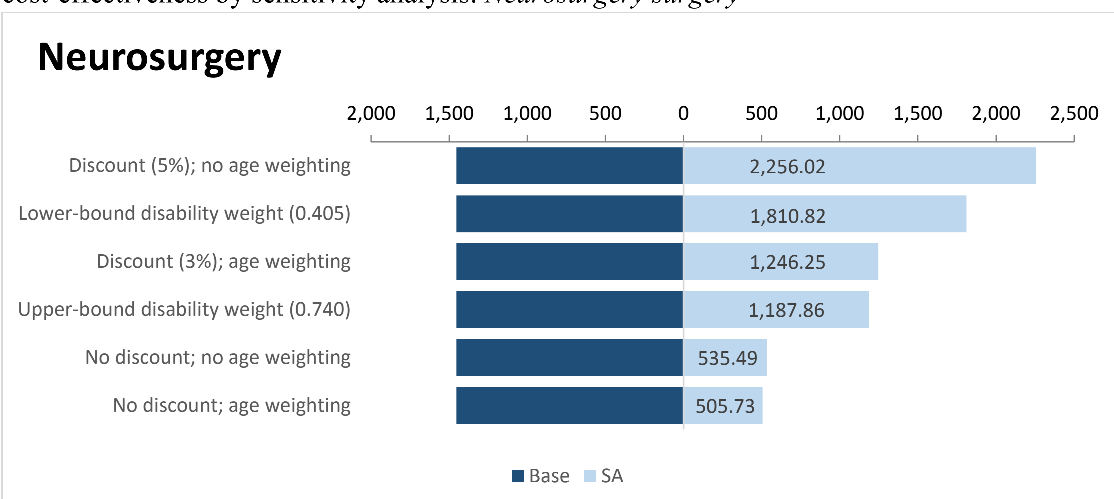

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Figure 6.3: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Plastic surgery*

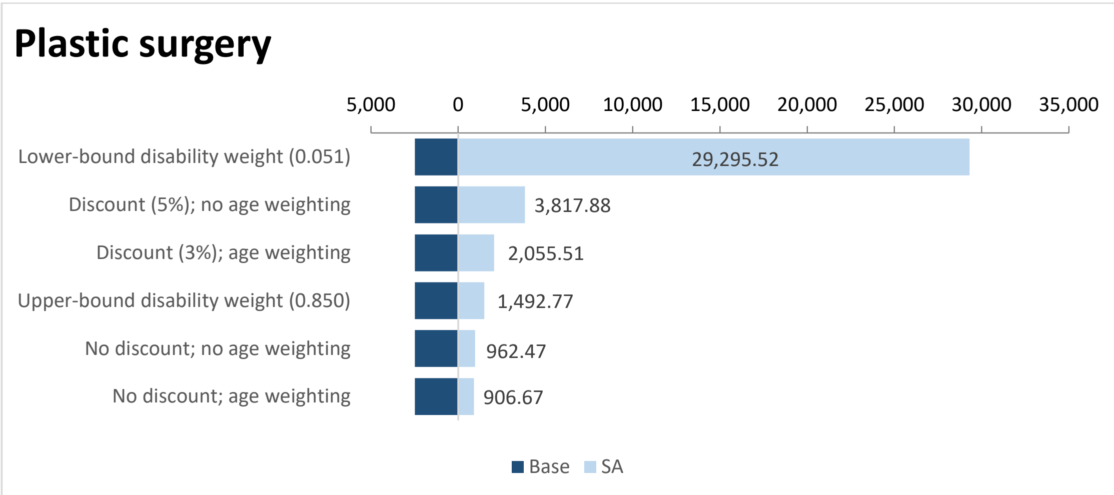

Figure 6.4: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Orthopedic surgery*

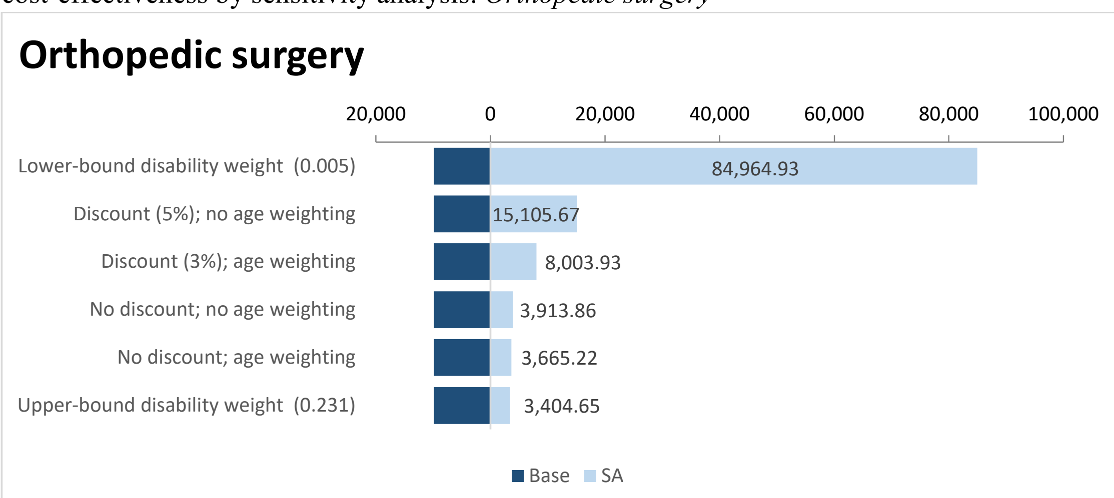

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Figure 6.5: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Pediatric general surgery*

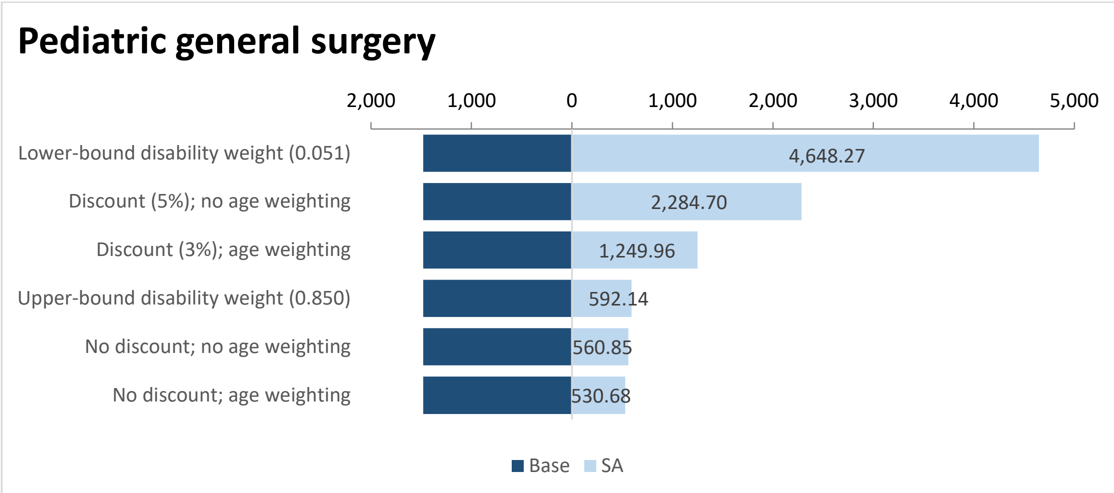
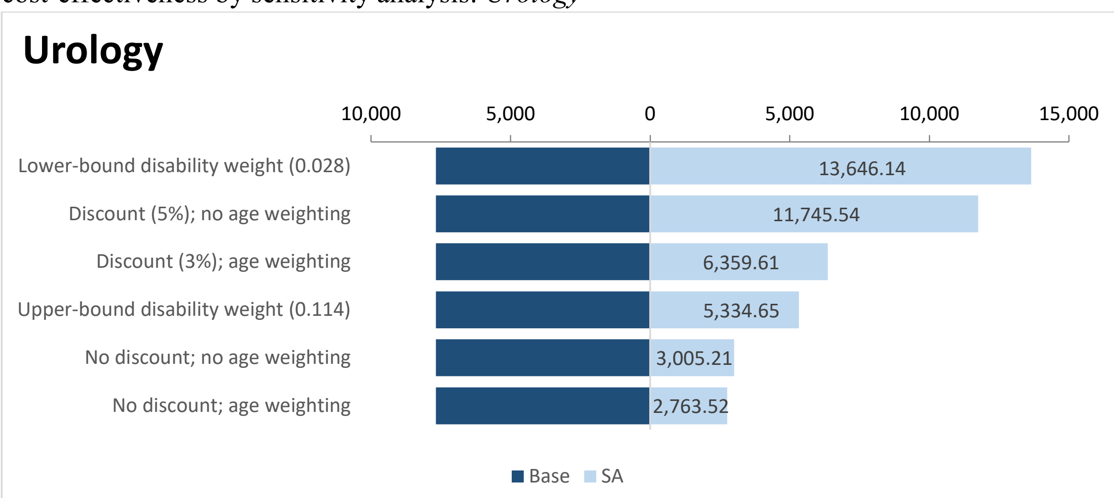


Figure 6.6: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Urology*



7. Cost-effectiveness analysis checklist

Table 6: Shrime's checklist for CEA's in global surgery

Assumptions	
1. Assumptions are made explicit.	✓
2. Assumptions that bias the ICER downward are avoided	✓
Analytic perspective and definition	

Table 6: Shrime's checklist for CEA's in global surgery

1. The base-case analysis is from the societal perspective. (Other perspectives may be included as secondary results.)	x
2. Results are reported for the intervention studied, including the platform and context for care delivery.	✓
3. Results are not generalized beyond what is explicitly studied.	✓
Measuring costs	
Which costs to include	
1. Costs to all levels of society are included:	x
a. The health ministry	x
b. The provider/hospital	✓
c. The patient's direct medical costs	✓
d. The patient's direct non-medical costs.	x
2. Indirect costs may be included if available in secondary analyses.	✓
Fixed costs	
3. Capital costs are annualized across the lifetime of the capital, taking into account resale value and discounting.	✓
4. Labor costs are explicitly detailed or are approximated by the salaries and benefits of the professionals in question.	✓
5. Salaries and benefits of visiting surgeons are included if they are involved	✓
Variable provider costs	
6. All variable costs are accounted for, including medications, supplies, and operating room time.	✓
Patient costs	
7. Direct medical costs include anything for which a patient has to pay because of surgery	x
8. Direct non-medical costs include transportation, food, lodging, and "informal payments" necessary to get care.	x
9. If caregivers commonly accompany patients, their direct costs are included.	x
Standardizing costs	
10. All costs are represented as international dollars, using GDP deflators and purchasing power parity conversion factors	✓
Discounting	
11. All future costs are discounted	✓
12. If a lifetime time horizon is used for discounting, age- and country-specific life tables determine life expectancy.	✓
Credibility	
13. The credibility of measured costs is checked against other available data.	✓

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Table 6: Shrime's checklist for CEA's in global surgery

Measuring effectiveness	
1. DALYs averted are the primary measure of effectiveness.	✓
2. Disability weights in the Global Burden of Disease studies are used if available. If the disability weight is unavailable, it is calculated from available data using a multiplicative formulation.	x
3. Subjective estimation of disability weights is avoided.	✓
4. The credibility of disability weights estimates is confirmed by comparing against other disability weights of the same magnitude.	✓
5. All future benefits are discounted at the same rate as future costs.	✓
6. Non-age-weighting disability weights are used as the base-case (age-weighting may be treated in scenario analyses)	✓
Estimating probabilities	
1. Decision trees are used to represent all possible eventualities for patients in the analysis.	x
2. Probabilities are determined directly from data or the literature.	x
3. Simplified and/or subjective probability estimates are avoided.	x
Valuing the counterfactual	
1. An incremental cost-effectiveness ratio, against the counterfactual of the status quo is reported	✓
2. If a simplified, average cost/effectiveness ratio is reported—that is, if the counterfactual is "nothing"—a *strong* case has been made that the studied intervention is never performed in the region of interest.	✓
Addressing heterogeneity and uncertainty	
1. Patient-level data are used to address heterogeneity. If patient-level data are not available, microsimulation methods may be used.	✓
2. All parameters are subjected to one-way, two-way, or probabilistic sensitivity analyses.	✓
3. Scenario analyses are included as relevant.	✓
4. ICERs are reported with appropriate uncertainty metrics.	✓

Note: ✓ indicates follows Shrime's recommendations, x indicates the data or methodological design does not follow Shrime's recommendations

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8. Supplemental material references

1. Baltussen RM, Adam T, Tan-Torres Edejer T, et al. *Making choices in health: WHO guide to cost-effectiveness analysis.* World Health Organization; 2003.

2. Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. *Methods for the economic evaluation of health care programmes.* Oxford university press; 2015.

3. Ozgediz D, Langer M, Kisa P, Poenaru D. Pediatric surgery as an essential component of global child health. . 2016;25(1):3-9.

4. Saxton AT, Poenaru D, Ozgediz D, et al. Economic analysis of children's surgical care in low- and middle-income countries: A systematic review and analysis. *PloS one*. 2016;11(10):e0165480.

5. World Health Organization. *The global burden of disease: 2004 update.* World Health Organization; 2008.

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7. Wang L, Wen H, Feng X, Jiang X, Duan X. Analysis of economic burden for patients with cystic echinococcosis in five hospitals in northwest china. *Trans R Soc Trop Med Hyg*. 2012;106(12):743-748.

8. Poenaru D, Pemberton J, Frankfurter C, Cameron BH. Quantifying the disability from congenital anomalies averted through pediatric surgery: A cross-sectional comparison of a pediatric surgical unit in Kenya and Canada. *World J Surg*. 2015;39(9):2198-2206.

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10. Gosselin RA, Gialamas G, Atkin DM. Comparing the cost-effectiveness of short orthopedic missions in elective and relief situations in developing countries. *World J Surg*. 2011;35(5):951-955.

Reporting checklist for economic evaluation of health interventions.

Based on the CHEERS guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the CHEERSreporting guidelines, and cite them as:

Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, Augustovski F, Briggs AH, Mauskopf J, Loder E. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement.

		Reporting Item	Page Number
Title			
	#1	Identify the study as an economic evaluation or use more specific terms such as “cost-effectiveness analysis”, and describe the interventions compared.	0
Abstract			
	#2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions	3
Introduction			
Background and objectives	#3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions	5-6

Methods

Target population and subgroups	#4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	6-11, Appendix 1
Setting and location	#5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	5,12
Study perspective	#6	Describe the perspective of the study and relate this to the costs being evaluated.	6
Comparators	#7	Describe the interventions or strategies being compared and state why they were chosen.	3,6
Time horizon	#8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	5
Discount rate	#9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate	9
Choice of health outcomes	#10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed	9-10 Appendix 5
Measurement of effectiveness	#11a	Single study-based estimates: Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data	10-11 Appendix 5
Measurement of effectiveness	#11b	Synthesis-based estimates: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data	10-11, Appendix 5
Measurement and valuation of preference based outcomes	#12	If applicable, describe the population and methods used to elicit preferences for outcomes.	NA

**Estimating resources

and costs **

	#13a	Single study-based economic evaluation: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs	8-9 appendix 2
Methods			
Estimating resources and costs	#13b	Model-based economic evaluation: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	8-9, appendix 2
Currency, price date, and conversion	#14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	7
Choice of model	#15	Describe and give reasons for the specific type of decision analytical model used. Providing a figure to show model structure is strongly recommended.	3,6-7
Assumptions	#16	Describe all structural or other assumptions underpinning the decision-analytical model.	10,19-22
Analytical methods	#17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	10
Results			
Study parameters	#18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show	Appendix 2

		the input values is strongly recommended.	
Incremental costs and outcomes	#19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	8-9, Appendix 2
Characterising uncertainty	#20a	Single study-based economic evaluation: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	17, Appendix 6
Characterising uncertainty	#20b	Model-based economic evaluation: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	17, Appendix 6
Characterising heterogeneity	#21	If applicable, report differences in costs, outcomes, or cost effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	NA
Discussion			
Study findings, limitations, generalisability, and current knowledge	#22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	17-22
Other			
Source of funding	#23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support	2
Conflict of interest	#24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations	2

Notes:

- 4: 6-9, Appendix 1
- 10: 7-8, Appendix 4
- 11a: 6, 9, Appendix 3
- 11b: 6, 9, Appendix 3
- 13a: 6-9, appendix 3
- 13b: 6-9, appendix 3 The CHEERS checklist is distributed under the terms of the Creative Commons Attribution License CC-BY-NC. This checklist was completed on 15. February 2021 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai