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)

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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 not 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.

- 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

- 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

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

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*

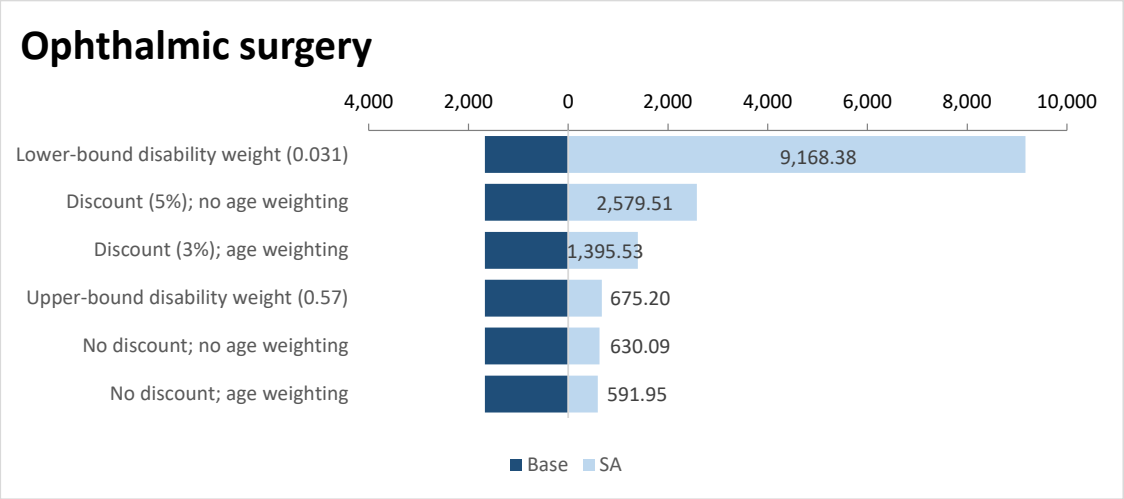


Figure 6.2: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Neurosurgery surgery*

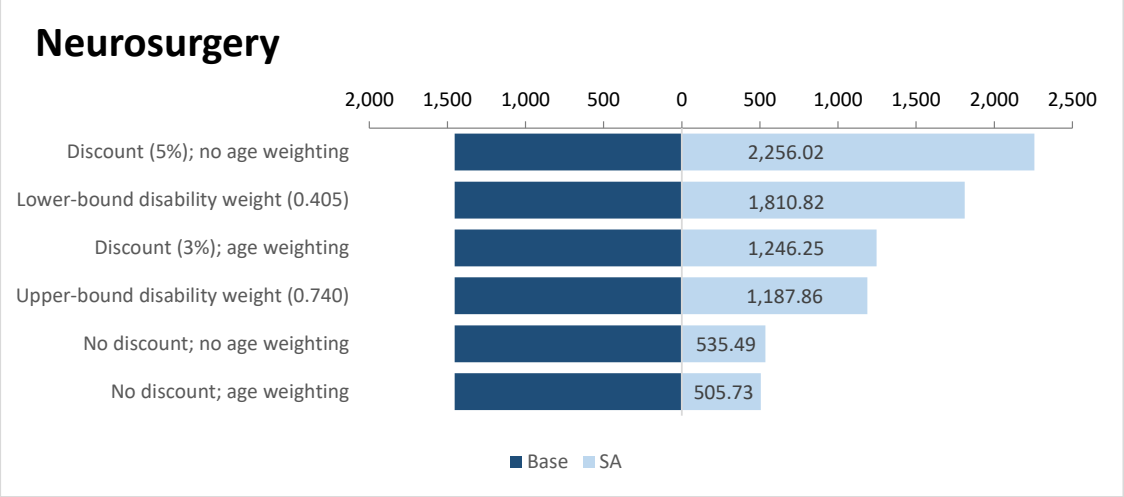


Figure 6.3: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Plastic surgery*

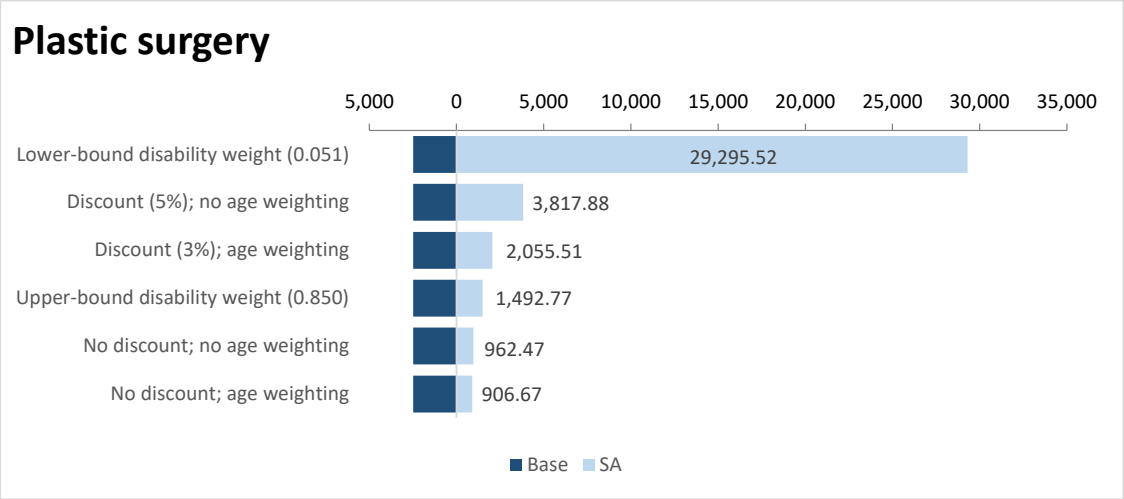


Figure 6.4: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Orthopedic surgery*

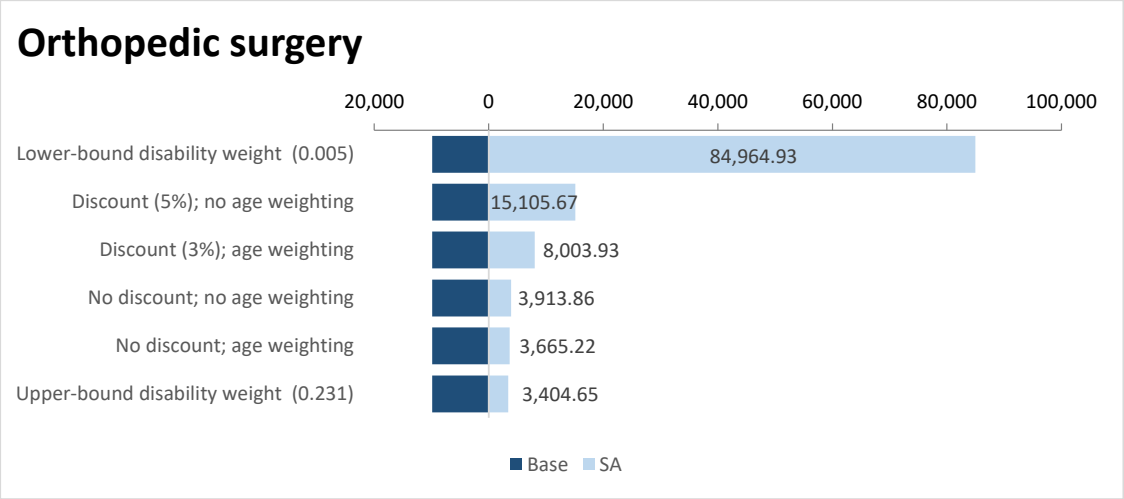


Figure 6.5: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Pediatric general surgery*

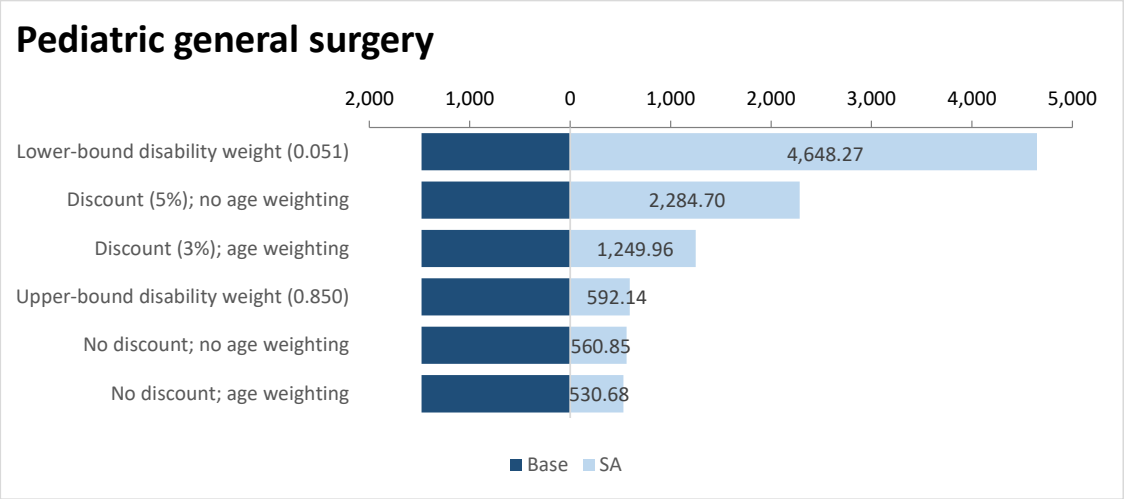
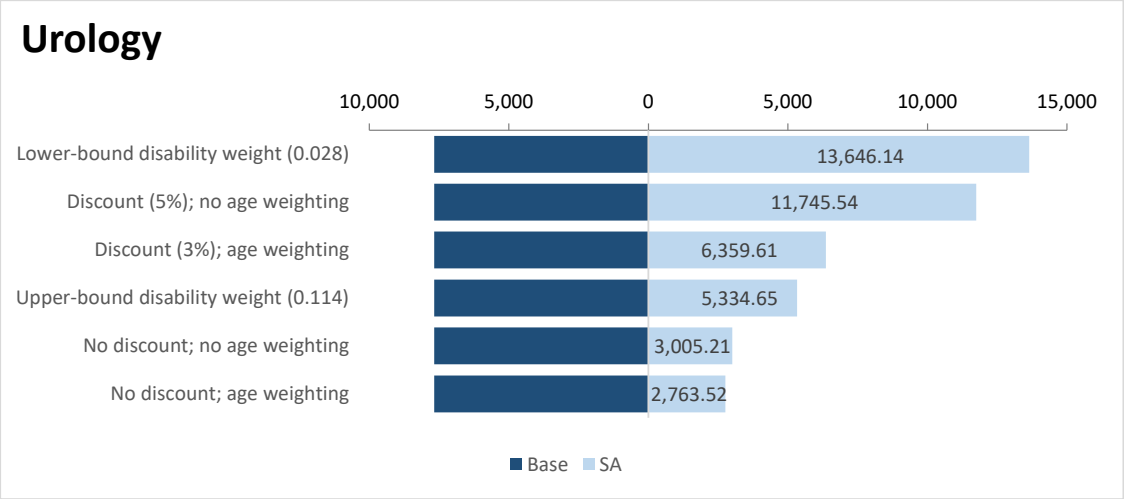


Figure 6.6: Tornado diagrams depicting the relative effect of key variables on pediatric surgery's cost-effectiveness by sensitivity analysis: *Urology*



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.	✓

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

8. Supplemental material references

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