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Research Paper

Effectiveness, cost-effectiveness, and economic impact of a multi-specialty charitable surgical center in Honduras

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ABSTRACT

Introduction: Despite significant demand and evidence indicating cost-effectiveness, surgical care is neglected in low- and middle-income countries (LMIC). Research indicates complex charitable surgical interventions are more effective in specialty hospitals than in short-term mission trips. This study aims to determine the effectiveness, cost-effectiveness, and economic impact of a multi-specialty charitable ambulatory surgical center in a LMIC.

Materials and methods: Surgeries performed at an ambulatory surgery center (ASC) in rural Honduras in six specialties were evaluated for a one-year period for complications, infections, and patient satisfaction. Each patient's decrease in disability was determined by the World Health Organization Disability Assessment Schedule (WHODAS 2.0), and these data were used to estimate the cost per Disability Adjusted Life Year (DALY) averted. Economic benefit was calculated by the human capital approach and the value of a statistical life (VSL) approach.

Results: Of the 963 surgeries performed, four patients (0.4%) experienced surgical site infections and 16 (1.6%) experienced complications, comparable to rates at ASCs in high-income countries. Cost per DALY averted was $638.08. The economic benefit was $17.9 million using the human capital approach and $328.4 million using the VSL approach.

Conclusions: Our findings suggest a multi-specialty charitable surgical center in a low-middle income country can achieve similar outcomes to surgery centers in high-income countries. The operations were slightly less cost-effective than many short-term surgical missions, likely due to the investment in equipment and local labor which leads to the more favorable outcomes. This model of charitable surgical care provides a substantial benefit to the population.

1. Introduction

The global burden of surgically treatable disease is significant, and the demand for surgery in low- and middle-income countries (LMICs) is disproportionally under-addressed [1,2]. Worldwide, the lack of adequate surgical care is estimated to result in $20.7 trillion of lost output during the next 15 years [3]. Each year, an estimated 32.8 million people face catastrophic expenditure due to surgically treatable disease, with an additional 3.7 billion at risk if they require surgery [4].

Surgical care has not been prioritized among health interventions in LMICs due to many factors. The relative paucity of detailed information and lack of consensus on the best strategy to improve surgical care has impeded surgical leaders from convincing policymakers of its necessity. Due in part to a persistent misconception that surgical care is prohibitively expensive, intervention from international NGOs to address the Millennium Development Goals has been focused on individual diseases as opposed to the broad improvements in infrastructure, supplies, and personnel necessary to improve surgical care [5–7]. However,

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evidence indicates many surgical procedures are as cost-effective as many commonly prioritized global health interventions such as vaccinations, bed nets, oral rehydration therapy, and anti-retroviral medications [8–10].

The increased activity in charitable surgical platforms resulting from these findings compels policymakers and donors to determine the most effective method of improving access to surgical care for low-income populations. A 2015 review of 104 studies demonstrates that surgical care in low-income countries results in better patient outcomes when performed in specialized hospitals as opposed to short-term surgical missions [11]. The review found short-term missions can effectively perform simpler procedures but are less appropriate for more complex surgeries. Cost-effectiveness data is abundant from short-term missions, but must be interpreted with caution due to generally less-desirable outcomes. Only two existing studies evaluate the cost-effectiveness of a specialty center [12,13], indicating more research is necessary.

Honduras is a low-middle income country with a population of 9.2 million and a health care system ranked 131 of 191 by the WHO [14]. Only 10% of Hondurans are covered by health insurance and 34% of health care financing comes from out of pocket expenditures [15]. There are 13.7 surgical care providers per 100,000 population in Honduras compared with 54.7 in the United States [16], and specialty hospitals only exist in the country's two largest cities, severely limiting access to elective surgery.

In order to address this gap, an ambulatory surgery center (ASC) was constructed on a children's home in rural Honduras that performs approximately 1,000 surgeries per year for patients of all ages in six specialties (Table 1). The center is 11,279 square feet and consists of three operating rooms, six pre-operative, six post-operative, and six step-down patient bays. While patients in some circumstances are allowed to stay overnight due to socio-economic factors, the center does not provide inpatient hospital services.

Since its initiation, the center has followed Joint Commission standards for ASCs in the United States, such as the sterilization of instruments according to the Association for the Advancement of Medical Instrumentation, infection prevention according to the Association of Professionals in Infection Control and Epidemiology, and operating room practices according to the Association of periOperative Registered Nurses. Surgical equipment is purchased or procured from donor manufacturing companies in advance of missions to ensure sufficient supply for all procedures performed.

The center's medical director is a Honduran orthopedic surgeon who performs or assists with many of the surgeries and oversees all pre- and post-operative clinic visits. Hondurans also make up the majority of the clinical and support staff. Volunteer surgeons from the United States and other high-income countries perform most of the surgeries, typically in one-week missions occurring once or twice per month. Volunteer orthopedic surgeons provide the medical director with ongoing training on innovative surgical techniques. Before being permitted to volunteer, visiting surgeons must present copies of their board certification, active hospital or surgery center credentials, and active state medical license. While surgical residents and medical students may assist in surgery, no medical trainee at any level is permitted to lead surgical procedures.

The center schedules clinic appointments for patients with acute trauma within two weeks or for those referred by a local physician during the next mission offering the desired specialty. During these appointments, surgeons rank patients from 1 to 4 by surgical urgency and social workers rank them from A to C based on socioeconomic need. Patient coordinators then fill available operating room slots in order of these combined rankings.

Although the structure of the organization allows surgeons from high-income countries to volunteer for brief intervals, unlike the short-term mission trips described by the 2015 review [11], the continuity provided by the full time local medical director and staff enables sufficient follow-up for surgical patients to both minimize adverse outcomes of complications and permit detailed data collection.

This study aims to describe the effectiveness, cost-effectiveness, and economic impact of this multi-specialty charitable ambulatory surgery center in a low-middle income country.

2. Materials and methods

To determine effectiveness as measured by the rate of surgical site infection or significant complications, all post-operative patients were screened according to guidelines from the Joint Commission [17]. Rates of infection and specific complications were descriptively compared with data from ambulatory surgery centers in high-income countries. Due to heterogeneity in disease conditions and locations, no direct comparison was performed with short-term surgical missions in other LMICs.

To determine patient satisfaction as another measurement of effectiveness, patients willing to participate completed the Outpatient and Ambulatory Surgery Consumer Assessment of Health Providers and Systems (OAS-CAHPS). Results from this survey were descriptively compared with national averages from ambulatory surgical centers in the United States (Press Ganey).

Regarding cost-effectiveness, whenever possible we followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) Statement [18] and the guidelines for cost-effectiveness analysis in global surgery proposed by Shrime [19], using the unit cost per disability-adjusted life year (DALY) averted. The DALY measures burden of disease by accounting for morbidity as well as premature mortality [20] and is calculated by the following equation:

$$\mathrm{DALY} = \mathrm{YLL} + \mathrm{YLD}$$

where YLL is years of life lost and YLD is years lost due to disability. We used a discounting rate of 3% per year without age-weighting [19,21].

Years lost to disability is equal to the product of the duration of the disease and the disease-specific disability weight, a number between 0 and 1 reported for many common diseases by the Global Burden of Disease Study [22], with 0 indicating perfect health and 1 meaning death. However, this center treats patients for a wide variety of disease states, many of which are not included in the standardized disability weights. Therefore, disability weights among patients before and after surgery were calculated by using the 12-point World Health Organization Disability Assessment Schedule (WHODAS 2.0) [23]. The WHODAS has been studied extensively for many diseases in both high- and low-income countries and has been found to be a valid and reliable measurement of disability and level of function [24].

All patients who received surgery from January 1 until December 31, 2017 were invited to participate in the study. Those willing to participate completed the WHODAS questionnaire by in-person interview prior to their surgery. We collected demographic information including age, sex, address, level of education, profession, monthly earnings, and time spent living with the surgical condition. Patients that completed the initial interview then repeated the WHODAS between three and six months after surgery, either by in-person interview or by telephone. The group of patients that completed the WHODAS both before and after surgery

Table 1
Complete surgical list.

Subspecialty	Surgery	Number	
Orthopedics	Anterior cruciate ligament repair	67	
	Knee arthroscopy	61	
	Total knee arthroplasty	50	
	Lower extremity hardware removal	49	
	Bunionectomy/osteotomy	38	
	Open reduction of tibia/fibula	25	
	Open reduction and internal fixation of radius	23	
	Arthrodesis	19	
	Revision of femur malunion	18	
	Debridement[a]	17	
	Mass excision (orthopedic)	16	
	Total hip arthroplasty	13	
	Shoulder arthroscopy	12	
	Open reduction and internal fixation of humerus	11	
	Open reduction of ankle	11	
	Cyst excision (orthopedic)	10	
	Amputation	9	
	Upper extremity hardware removal	9	
	Nail bed repair	9	
	Hand surgery (other)	8	
	Bankart shoulder repair	7	
	Fasciotomy/fasciectomy	7	
	Achilles tendon lengthening	7	
	Revision of tibia malunion	5	
	Open reduction of patella	5	
	Bone cement removal	5	
	Quadriceps/patellar tendon repair	5	
	Distal clavicle excision	4	
	Open reduction of elbow	4	
	Open reduction of finger/hand	4	
	Tendon transfer	4	
	Carpal tunnel release	4	
	Foot/ankle surgery (other)	4	
	Hallux rigidus correction	3	
	Revision of humerus malunion	3	
	Open reduction of clavicle	3	
	Trigger finger/thumb release	3	
	Bone graft	3	
	Open reduction and internal fixation of hip	2	
	Clubfoot correction	2	
	Achilles tendon repair	2	Total orthopedics
	Other orthopedics	21	582
General surgery	Laparoscopic cholecystectomy	56	
	Inguinal herniorrhaphy	46	
	Umbilical hernia repair	26	
	Mass excision (general surgery)	17	
	Thyroid lobectomy	12	
	Total thyroidectomy	10	
	Breast lumpectomy	9	
	Ventral (incisional) hernia repair	7	
	Mastectomy	6	
	Hydrocelectomy	6	
	Skin graft	6	
	Breast biopsy	4	
	Partial thyroidectomy	4	
	Lymph node excision (general)	2	Total general surgery
	Other general surgery	7	218
Otolaryngology	Tonsillectomy and adenoidectomy	18	
	Tonsillectomy	16	
	Septoplasty/reduction of inferior turbinate fracture	9	
	Mass excision (otolaryngology)	3	
	Adenoidectomy	2	
	Frenulectomy	2	
	Cyst excision (otolaryngology)	2	Total otolaryngology
	Other otolaryngology	10	62
Urology	Transurethral prostate resection	19	
	Cystoscopy	10	
	Mid urethral sling	7	
	Circumcision	4	
	Orchiopexy	1	Total urology
	Orchiectomy	1	42

(*continued on next page*)

Table 1 (*continued*)

Subspecialty	Surgery	Number	
Ophthalmology	Cataract surgery	33	
	Pterygium removal	5	
	Strabismus surgery	2	Total ophthalmology
	Scar revision	1	41
Gynecology	Vaginal hysterectomy	4	
	Rectocele repair	3	
	Tension free vaginal taping	3	
	Abdominal hysterectomy	3	
	Cystocele repair	2	
	Laparoscopic ovarian cystectomy	2	Total gynecology
	Colpocleisis	1	18
Total		**963**	

[a] Debridement refers to surgical cleaning and removal of devitalized tissue involving deep orthopedic infections for patients referred from other medical facilities.

was compared to the group that did not with respect to age, sex, and surgical subspecialty via chi-squared tests.

For the WHODAS group, we calculated the total and mean DALYs averted by surgical procedures overall and stratified by sex, surgical subspecialty, and decade of life. We assumed no years of life were lost (YLL = 0) so the DALY calculation is based only on years lost due to disability (YLD). Therefore, DALYs averted were calculated with the following equation:

$$\text{DALYs averted} = [DW\ (pre) - DW\ (post)]*\left\{\frac{1}{r}\left(1 - e^{-rL}\right)\right\}$$

Here, duration of disease (L) was the remaining life-expectancy at age of surgery from the WHO global health observatory data repository [25], and the discounting rate (r) was 0.03 [20]. The disability weight was the difference between the WHODAS score before surgery and the score three to six months after surgery (including patients whose disability increased). We then estimated the total DALYs averted for the entire cohort based on the observed DALYs averted from the WHODAS subgroup, and provided ranges based on two standard deviations above and below the mean estimates.

The cost-effectiveness ratio was calculated by dividing the total cost during the one-year study period by the estimated total DALYs averted by all surgeries performed. The total operating costs of the surgical center included wages for local staff, travel expenses for volunteers, equipment and supplies (including shipping), depreciation of building and infrastructure, repairs and maintenance, and utilities. As recommended by Shrime [19], we also included the estimated value of all donated equipment and supplies as well as the opportunity cost of foregone salary for all volunteers, including surgeons, nurse anesthetists, nurses, and technicians. Similarly, we included estimates for expenses incurred by patients and their caregivers in order for the patient to receive surgery, such as food, transportation, and lodging.

The economic benefit of the operations was estimated by two methods: the human capital approach and the value of a statistical life (VSL) approach. The human capital approach provides a conservative estimate by multiplying the number of DALYs averted by the Honduran gross national income per capita. For a more comprehensive estimate to value human life, economists have developed a methodology called value of a statistical life (VSL) [26,27]. Used by government agencies such as the United States Department of Transportation and Environmental Protection Agency (EPA) for policy decisions, VSL is calculated from cumulative observations on the pay cut workers are willing to accept in order to decrease the risk of mortality on the job. Our methodology for this calculation was taken from two papers by Alkire [28] and Warf [29] estimating the potential benefit of two distinct interventions in global surgery. Using the EPA's VSL estimate for the United States and the income elasticity factor of 0.55 calculated by a review of relevant studies [30], the VSL year (VSLY) of Honduras was calculated as follows:

$$VSLY = V*DALY[3, 1, 0.02]$$

where V is equal to

$$V = \frac{VSL(Honduras)}{\tilde{c}} * \frac{(\tilde{\beta} + r)^2}{1 - e^{-(\tilde{\beta}+r)L}[1 + L(\tilde{\beta} + r)]}$$

and VSL (Honduras) was determined from VSL (US) and the ratio of Honduran GNI to US GNI, using the following equation:

$$VSL(Honduras) = VSL(US)*\left[\frac{GNI(Honduras)}{GNI(US)}\right]^{0.55}$$

As the VSLY approach recommends discounting and age-weighting, an age-weighting constant ($\beta = 0.02$) was calculated to reflect VSLY peaking at 2/3 of the life expectancy for Honduras [28,29]. The value of the age-weighting correction constant (c) was determined from Table 5.2 in the Global Burden of Disease and Risk Factors [22]. We provided a range of estimates for both human capital and VSL approaches based on the ranges of total estimated DALYs as described above.

Adults willing to complete the WHODAS and OAS-CAHPS signed informed consent to participate in this study. For patients under 18 years of age, parents answered the questions on the patients' behalf and signed consent (with verbal assent for patients aged 7–18).

3. Results

963 surgeries were performed during the study period: 582 (60.4%) in orthopedics, 218 (22.6%) in general surgery, 62 (6.4%) in otolaryngology, 42 (4.4%) in urology, 41 (4.3%) in ophthalmology, and 18 (1.9%) in gynecology (Table 1).

Four patients (0.4%) experienced surgical site infections and 16 (1.6%) experienced complications that required unexpected follow up treatment (Table 2). Specifically, the rate of wound dehiscence was 0.1%, the rate of post-operative hemorrhage/hematoma was 0.3%, and the rate of dislocated ocular lens following cataract surgery was 18.2%.

537 patients (55.8%) completed the patient satisfaction survey (Table 3). On a scale of 0–10, the mean reported satisfaction with surgical outcome was 9.75, and the mean rating for the facility was 9.95. 98.3% of patients said they would definitely recommend the facility to friends and family. For the remaining 17 questions relating to communication, respect, cleanliness, and management of expectations, patients responded “yes, definitely” 92.7% of the time.

Table 2
Infections and complications requiring unexpected treatment.

Surgery	Complication	Complication/infection rate by subspecialty
Anterior cruciate ligament repair	Hematoma, post-operative superficial surgical site infection	Orthopedics: 0.9%
Total knee arthroplasty	Fall outside of facility causing partial quadriceps tendon tear requiring open repair	
Repair of hand fracture	Hematoma; wound dehiscence, requiring clinic treatment	
Total knee arthroplasty	Post-operative hospital transfer for urinary retention	
Olecranon bursal tophus excision at elbow	Superficial Hematoma, drained in clinic	
Laparoscopic cholecystectomy	Post-operative superficial surgical site infection	General surgery: 1.4%
Umbilical hernia repair	Post-operative superficial surgical site infection	
Laparoscopic Cholecystectomy	Post-operative superficial surgical site infection	
Cataract surgery	Dislocated intraocular lens	Ophthalmology: 22.0%
Cataract surgery	Dislocated intraocular lens	
Cataract surgery	Dislocated intraocular lens	
Cataract surgery	Severe corneal edema	
Cataract surgery	Suprachoroidal hemorrhage	
Cataract surgery	Dislocated intraocular lens	
Cataract surgery	Incomplete cataract extraction with retained lens fragments	
Cataract surgery	Dislocated intraocular lens	
Cataract surgery	Dislocated intraocular lens	
Vaginal hysterectomy	Post-operative fistula	Gynecology: 5.6%

Table 3
Patient satisfaction results.

Patient Satisfaction Results (Adapted from OAS-CAHPS)	Yes, definitely (Honduran Surgery Center)	Yes, Definitely (United States Ambulatory Surgery Center Average)
Before your procedure, did your doctor or anyone from the facility give you all the information you needed about your procedure?	94.5%	91.1%
Before your procedure, did your doctor or anyone from the facility give you easy to understand instructions about getting ready for your procedure?	97.1%	94.2%
Did the check-in process run smoothly?	93.4%	95.2%
Was the facility clean?	99.6%	98.1%
Were the clerks and receptionists at the facility as helpful as you thought they should be?	98.4%	96.0%
Did the clerks and receptionists at the facility treat you with courtesy and respect?	100%	97.8%
Did the doctors and nurses treat you with courtesy and respect?	99.8%	98.0%
Did the doctors and nurses make sure you were as comfortable as possible?	98.9%	96.8%
Did the doctors and nurses explain your procedure in a way that was easy to understand?	94.8%	93.1%
Did your doctor or anyone from the facility explain the process of giving anesthesia in a way that was easy to understand?	92.6%	93.1%
Did your doctor or anyone from the facility explain the possible side effects of the anesthesia in a way that was easy to understand?	86.3%	82.0%
Did your doctor or anyone from the facility prepare you for what to expect during your recovery?	89.7%	86.4%
Some ways to control pain include prescription medicine, over-the-counter pain relievers or ice packs. Did your doctor or anyone from the facility give you information about what to do if you had pain as a result of your procedure?	92.1%	95.2%
Before you left the facility, did your doctor or anyone from the facility give you information about what to do if you had nausea or vomiting?	80.7%	96.8%
Before you left the facility, did your doctor or anyone from the facility give you information about what to do if you had bleeding as a result of your procedure?	81.3%	97.3%
Possible signs of infection include fever, swelling, heat, drainage or redness. Before you left the facility, did your doctor or anyone from the facility give you information about what to do if you had possible signs of infection?	77.9%	99.0%
Would you recommend this facility to your friends and family?	98.3%	84.2%
Using any number from 0 to 10, where 0 is the worst facility possible and 10 is the best facility possible, what number would you use to rate this facility?	Mean = 9.95	Mean = 8.59
On a scale of 0–10, 0 being completely unsatisfied and 10 being completely satisfied, how satisfied are you with your surgical outcome?	Mean = 9.75	Mean = 8.42

580 patients (60.2%) completed the WHODAS questionnaire both before surgery and between three and six months after surgery (Table 4). The average time the patients were living with their conditions before receiving surgery was 4.6 years. There was no significant difference in the WHODAS and the non-WHODAS group in terms of sex and age, but there was a significant difference between the two groups in terms of surgical subspecialty ($p = 0.008$). Therefore, a weighted-sum approach with DALYs averted stratified by surgical subspecialty was used to estimate the total DALYs averted in the entire cohort (Table 5). The mean decrease in disability among the 580 patients from before to after surgery was 20.7%. Using this figure as the mean change in disability weight, 4153.81 (3504.84–4802.78) DALYs were averted during the one-year period, which equals 4.31 (3.94–4.66) per surgery.

The total cost of the surgical center for the year was $2,650,458 (Table 6). Using this cost estimate, the cost per DALY averted was $638.08 ($551.86–756.23). The economic benefit of the surgeries performed, as calculated by the human capital approach, using discounting without age-weighting was $18.3 million ($15.5 - $21.2 million). Using the value of a statistical life approach with age-weighting and discounting as described above, the calculated benefit was $328.4 million ($276.7 - $380.1 million).

Table 4
Summary of cohort.

	Total	Non-WHODAS	WHODAS	P-value[a]
	(n = 963)	(n = 383)	(n = 580)	
Sex				
Female	461 (47.9)	180 (47.0)	281 (48.5)	0.659
Male	502 (52.1)	203 (53.0)	299 (51.6)	
Subspecialty				
Orthopedics	582 (60.4)	240 (62.7)	342 (59.0)	0.008
General surgery	218 (22.6)	74 (19.3)	144 (24.8)	
Otolaryngology	62 (6.4)	34 (8.9)	28 (4.8)	
Urology	42 (4.4)	20 (5.2)	22 (3.8)	
Ophthalmology	41 (4.3)	10 (2.6)	31 (5.3)	
Gynecology	18 (1.9)	5 (1.3)	13 (2.2)	
Age				
0–9 years	43 (4.5)	25 (6.5)	18 (3.1)	0.214
10–19 years	75 (7.8)	30 (7.8)	45 (7.8)	
20–29 years	173 (18.0)	68 (17.8)	105 (18.1)	
30–39 years	154 (16.0)	57 (14.9)	97 (16.7)	
40–49 years	131 (13.6)	46 (12.0)	85 (14.7)	
50–59 years	168 (17.5)	71 (18.5)	97 (16.7)	
60–69 years	132 (13.7)	47 (12.3)	85 (14.7)	
70–79 years	71 (7.4)	30 (7.8)	41 (7.1)	
80–89 years	15 (1.6)	8 (2.1)	7 (1.2)	
90–99 years	1 (0.1)	1 (0.3)	0 (0.0)	

[a] P-value from chi-squared test.

4. Discussion

Our findings indicate that post-operative complication and infection rates, as well as patient satisfaction of surgeries performed at a charitable multi-specialty surgical center in rural Honduras were similar to those found in ambulatory surgical centers in the United States. While our observed SSI incidence is lower than that of all surgeries performed in many high- and low-income countries, it should be noted that as an ASC, this center does not manage emergent cases or provide care to poly-traumatized patients. When compared with the SSI rate from 284,098 patients in ASCs across eight states in the US (3.09 per 1000), our results were similar [31].

The clear exception to our positive findings regarding complications was cataract removal, for which rate of dislocated intraocular lens was much higher than those found in previous studies [32,33], likely due to improper choice of operative technique made by one volunteer ophthalmologist. While phacoemulsification is now the gold standard for the early presentations of cataracts seen in high-income countries, the patients of the complication group had a mean age of 74 years and time spent living with cataract of 30.5 months. Extracapsular cataract extraction or manual small-incision cataract surgery are more appropriate techniques for advanced, hardened cataracts [34] and therefore would have been a better choice than phacoemulsification for this population. These findings have led the surgery center to create a physician leadership council to screen new volunteers for experience in low-resource settings and provide guidelines for appropriate techniques, which we would advise for any similar intervention.

Table 6
Complete costs for surgery center, 2017.

Labor (local staff)	$209,976	
Purchased equipment and supplies	$331,140	
Travel	$196,028	
Utilities	$44,579	
Repairs and maintenance	$38,377	
Shipping	$16,929	
Housekeeping & janitorial	$10,662	
Depreciation of building and infrastructure	$22,449	
Patient/caregiver transportation and lodging	$72,525	
Food for patients and caregivers	$11,604	
Donated equipment and supplies	$633,228	
Volunteered time of professionals	$1,062,960	
(physicians)		($816,000)
(certified registered nurse anesthetists)		($48,960)
(nurses/other clinicians)		($198,000)
Total expenses	**$2,650,458**	

Using the cost-effectiveness standard of the World Health Organization, cost per DALY averted versus the national GDP of Honduras ($2,361), our results suggest that the surgeries performed were very cost-effective interventions (cost per DALY less than national GDP).

Although our findings indicate operations performed at this surgical center were less cost-effective than those of many short-term surgical mission trips, our data regarding complication and infection rates suggest generally more favorable outcomes [8–11,35–37]. While many short-term mission trips rely on infrastructure and equipment that is available locally, this center was built specifically for missions and used $964,368 in purchased and donated equipment during the one-year study period. This, in addition to making a noteworthy expenditure on the salaries of the medical director and local staff, which allows for more consistent follow-up for patients and improved communication with volunteer surgeons before and after missions, likely leads to better outcomes.

As discussed by Shrime's 2017 guidelines [19], it is necessary to compare the intervention in question with the most likely alternative. Since the lowest-income patients were prioritized for treatment, and since patients had lived with their conditions for an average of 4.6 years before receiving surgery, it is most reasonable to assume these patients would not otherwise have received surgery from the Honduran medical system. However, uncertainty in this regard is one of this study's limitations.

Another limitation is that we estimated both the patient satisfaction and mean decrease in disability per surgery (and subsequently cost-effectiveness) based on the subgroup of patients who

Table 5
Total and mean DALYs averted by surgical subspecialty.

Surgical subspecialty	Observed from WHODAS subgroup (N = 580)		Estimated for entire cohort (N = 963)
	Total DALYs averted [3,0,0][a]	Mean[b] DALYs averted [3,0,0][a]	Total[b] DALYs averted [3,0,0]
Orthopedics	1777.21	5.20 (4.70, 5.70)	3024.37 (2733.60, 3315.13)
General surgery	458.12	3.18 (2.55, 3.82)	693.55 (555.35, 831.75)
Otolaryngology	77.00	2.75 (1.65, 3.85)	170.49 (102.23, 238.76)
Urology	35.88	1.63 (0.15, 3.11)	68.49 (6.45, 130.53)
Ophthalmology	83.57	2.70 (1.66, 3.73)	110.53 (68.16, 152.91)
Gynecology	62.39	4.80 (2.17, 7.43)	86.38 (39.05, 133.71)
Total	2494.16	4.30 (3.94, 4.66)	4153.81 (3504.84, 4802.78)

[a] Discount rate = 3%, no age-weighting.
[b] To account for uncertainty in estimates, we provide ranges based on 2 standard errors above and below the estimated mean.

were willing and able to complete the surveys before and after surgery, which may not be representative of the entire 963-patient population. We were able to at least partially adjust our results for the difference in proportion of surgical subspecialties by using the weighted-sum technique.

A final limitation is that DALYs averted are most often calculated by standardized disability weights [22], which are considered valuation measures, as opposed to the WHODAS, which is considered a descriptive measure [23]. However, all cost-effectiveness studies must make assumptions to calculate decreases in disability, such as by using estimates for similar procedures or from previous experience [20,38,39]. The advantage of our methodology is that it uses information collected from actual patients before and after their surgeries. In fact, several cost-effectiveness studies that use standardized disability weights or the other assumptions described above postulate that measuring the disability in each individual patient treated would provide a more accurate estimate [10,40]. Furthermore, our findings regarding the complication and infection rates of the surgeries performed, as well as on patient satisfaction, add plausibility to the observed decrease in disability determined by the WHODAS.

5. Conclusion

Our findings suggest that a multi-specialty charitable ambulatory surgical center in a low-middle income country that maintains high-income-country level quality standards and relies principally on local support staff is slightly less cost-effective than are short-term surgical missions, but is likely more effective in terms of patient outcomes. Surgeries performed at this center remain very cost-effective by WHO standards and provide substantial economic benefit to the patient population.

Ethical approval

1. National Autonomous University of Honduras, Faculty of Medical Sciences, Committee of Ethics in Biomedical Research, reference number IRB 00003070.
2. Office of Research Integrity and Compliance, Ann & Robert H. Lurie Children's Hospital of Chicago, Northwestern University School of Medicine, reference number IRB 2017-1104.

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Author contribution

Darren Eblovi contributed to the study design, data analysis, and writing.

Merlin Antunez contributed to the study design and data collection.

Kate Clitheroe contributed to the study design, data collection, and writing.

Monica Meeks contributed to the study design, data collection, and writing.

Lauren Balmert contributed to the study design, data analysis, and writing.

Hollie Thornton contributed to the study design.

David West contributed to data collection.

Nicholas Waldvogel contributed to data analysis.

Peter Daly contributed to the study design, data collection, and writing.

Conflict of interest statement

None.

Guarantor

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijso.2019.08.002.

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