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Economic Evaluation

Cost-Effectiveness Analysis of Inguinal Hernia Repair With Mesh Performed by Surgeons and Medical Doctors in Ghana

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ABSTRACT

Objectives: Task-sharing is the pragmatic sharing of tasks between providers with different levels of training. To our knowledge, no study has examined the cost-effectiveness of surgical task-sharing of hernia repair in a low-resource setting. This study has aimed to evaluate and compare the cost-effectiveness of mesh repair performed by Ghanaian surgeons and medical doctors (MDs) following a standardized training program.

Methods: This cost-effectiveness analysis included data for 223 operations on adult men with primary reducible inguinal hernia. Cost per surgery was calculated from the healthcare system perspective. Disability weights were calculated using pre- and postoperative pain scores and benchmarks from the Global Burden of Disease Study 2017.

Results: The mean cost/disability-adjusted life-year (DALY) averted in the surgeon group was 444.9 United States dollars (USD) (95% confidence interval [CI] 221.2-668.5) and 278.9 USD (95% CI 199.3-358.5) in the MD group (P = .168), indicating that the operation is very cost-effective when performed by both providers. The incremental cost/DALY averted showed that task-sharing with MDs is also very cost-effective (95% bootstrap CI −436.7 to 454.9). The analysis found that increasing provider salaries is cost-effective if productivity remains high. When only symptomatic cases were analyzed, the mean cost/DALY averted reduced to 232.0 USD (95% CI 17.1-446.8) for the surgeon group and 129.7 USD (95% CI 79.6-179.8) for the MD group (P = .348), and the incremental cost/DALY averted increased by 45% but remained robust.

Conclusions: Elective inguinal hernia repair with mesh performed by Ghanaian surgeons and MDs is a low-cost procedure and very cost-effective in the context of the study. To maximize cost-effectiveness, symptomatic patients should be prioritized over asymptomatic patients and a high level of productivity should be maintained.

Keywords: cost-effectiveness analysis, global surgery, hernia repair, task-sharing.

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Introduction

The provision of effective care for essential surgical conditions is now recognized as a crucial component of global healthcare delivery.[1,2] Once thought to be too expensive in resource-constrained settings, essential surgical care has been shown to be cost-effective in low- and middle-income countries (LMICs).[3-14] Using varying methodologies, studies have demonstrated cost-effectiveness of surgery for many conditions in LMICs, including inguinal hernia, obstetric emergencies, cataracts, and cardiac disease.[6-9,11,12,15]

We estimate that inguinal hernia affects 547 million people globally, including nearly 1 million people in Ghana.[5,16] Limited access to inguinal hernia repair in LMICs leads to negative effects on well-being and productivity.[5] In 1 Ghanaian cohort study, 16% of hernia patients reported an inability to work, whereas 64% reported limitations in daily activities.[17] Increased capacity for high-quality, cost-effective elective inguinal hernia repair is urgently needed in low-resource settings to alleviate the suffering of hernia patients and prevent potentially life-threatening complications.[18]

Advocated by the World Health Organization (WHO) to increase access to healthcare, task-sharing is the pragmatic sharing of tasks between providers with different levels of training.[19,20] Task-sharing of surgical procedures with nonsurgeons is common, especially in settings with limited human resources.[21,22] Multiple studies have demonstrated that nonsurgeons can perform surgical procedures, including cesarean section, laparotomy, and inguinal hernia repair with similar results compared with surgical specialists.[23-28] In Ghana, task-sharing of surgical procedures between surgeons and medical doctors (MDs), who are doctors with limited formal training in surgery, is widely practiced.[29-31] In fact, most inguinal hernia repairs in Ghana are performed by MDs.[30,31] Our previous research indicates that both surgeons and MDs can perform elective mesh inguinal hernia repair in Ghana with excellent outcomes, nevertheless, to our

knowledge, the effect of task-sharing on cost-effectiveness of inguinal hernia repair has not been studied before.[15]

The purpose of this study was to compare the cost-effectiveness of inguinal hernia repair with mesh performed by Ghanaian surgeons and MDs following a standardized training program. The results of this study will add to understanding of the impact of task-sharing on mesh hernia repair cost-effectiveness and serve to inform policy makers on the cost-effectiveness of providing elective mesh inguinal hernia repair in healthcare settings with human resource constraints.

Methods

Training Course and Materials

Developed in 2017, the Ghana Hernia Society's mesh repair training program utilizes Ghana's existing system of task-sharing to train both surgeons and MDs through lectures and supervised operations.[15] Following completion of the inaugural course, trainees (2 surgeons and 3 MDs) performed 242 open inguinal hernia repairs under local anesthesia on adult men with primary reducible hernias. Hernias were repaired according to the Lichtenstein technique using commercial polypropylene mesh purchased in Ghana. The MDs had completed medical school followed by a 2-year general internship but had no formal training in surgery. The surgeons had completed 6 years of postgraduate training in general surgery. Only trainees currently performing open tissue inguinal hernia repair were trained, and 1 surgeon trainee reported experience with mesh inguinal hernia repair. A previously published investigation found that MD trainees were noninferior to surgeons in terms of 1-year hernia recurrence (0.9% vs 2.8%, respectively) with equivalent rates of postoperative complications, chronic pain, and patient satisfaction.[15]

Study Setting and Procedures

This study was conducted in Ghana, which is a lower-middle income country in West Africa. Although Ghana's economy has been growing rapidly, an estimated 11.2% of people live on 1.90 United States dollars (USD) per day, the incidence of multidimensional poverty is 45.6%, and Ghana ranks 140 out of the 189 countries and territories on the Human Development Index.[32-34] In 2003, Ghana became one of the first countries in the sub-Saharan African region to propose a government sponsored social health insurance system, the national health insurance scheme (NHIS).[35] Although Ghana's NHIS was designed to be equitable and progressive, studies have found that individuals enrolled often make out-of-pocket payments at the point of care, and up to 18% of NHIS-insured Ghanaians make catastrophic healthcare payments.[35]

The study site was in Ho, Ghana at the Volta Regional Hospital, a 306-bed referral hospital for the Volta region under the management of the Ghana Health Service. The hospital Finance, Procurement, and Human Resource Departments provided information about hospital budget, supplies, and payroll for 2017. Individual participants gave written informed consent to participate in the initial cohort study.[15] Of the 242 patients in the original study, 223 (92.1%) were available for follow-up at 1 year.[15] Because this cost analysis relies on postoperative pain scores at 1 year, only the patients who completed 1 year follow-up (n = 223) were included. We used deidentified clinical information for these 223 patients, including patient age, operative time, and pre- and postoperative pain scores.[15] The overall rate of severe postoperative pain at 1-year follow-up was 2.2%, with no difference between patients in the MD or surgeon groups. Further information about pre- and postoperative pain scores may be found in the results of the previously published outcomes study.[15] The Temple University Institutional Review Board and the Ghana Health Service Ethical Review Committee approved this study.

Cost and Cost-effectiveness Analysis

This study is a cost-effectiveness analysis (CEA) of inguinal hernia repair with mesh performed by MDs and surgeons following the mesh hernia repair training program described above. First, we assessed generalized cost-effectiveness of the hernia operation performed by either provider, compared with no treatment. This analysis is most applicable to settings where there are limited or no specialist surgeons in Ghana. Then, we analyzed relative cost-effectiveness of the operation performed by MDs compared with surgeons. This analysis serves to further inform the allocative efficiencies of surgical task-sharing in contexts where human resources are less scarce. We designed our analysis using the recommendations from WHO guide to CEA (2003)[36] and from Drummond and Sculpher (2005).[37]

Costs from the healthcare system and providers' perspective were used, including staff time, medicine and material costs, overhead costs, capital costs, and equipment costs (see Table 1). Because medicines and materials were standard for each operation, a standard consumption was used for cost calculations. The cost for the commercially available mesh purchased for use in this study was 11 USD, and the mesh was paid for from the original training course budget. Operating room staff costs were calculated based on daily salary divided by 5, which was the standard number of hernia repairs performed by each provider and team per day. Salaries for ancillary staff were added to the hospital stay calculation. Per hospital policy, patients paid a standard out-of-pocket operation cost, which we included in our analysis. Because we did not collect cost data from patients, no indirect patient costs were included.

Overhead costs were estimated based on space per square foot in the operating rooms and surgical wards along with the use of ancillary services (Table 1). Capital costs were calculated for the area used in the operating rooms and surgical wards along with any equipment used, accounting for depreciation. Costs were converted from Ghanaian cedis to USD using the 2017 exchange rate.[38] No discounts were applied to costs as there were minimal expected needs for additional healthcare for limited long-term complications after elective inguinal hernia repair.

Disability-adjusted life-year (DALY) is defined as the sum of the measure of years of life lived with a disability (YLD) and years of life lost (YLL). A value of 1 represents full health, whereas a value of 0 represents death. Following methods from previous global surgery CEAs, costs and DALYs averted were calculated for each individual patient.[11,12,14] To determine YLD, we used patient responses to the Inguinal Pain Questionnaire (IPQ) preoperatively and 1-year postoperatively.[39] The IPQ is a 7-level scale in which a score of 1 represents no pain, 2 to 3 indicates mild pain that does not interfere with daily activities, 4 to 5 indicates pain that is moderate and debilitating, and 6 to 7 represents severe pain, which prevents daily activities completely.[39] Disability weights (DWs) were determined by matching the IPQ score for each patient with DWs used for inguinal hernia in the Global Burden of Disease Study 2017 (Table 2[21,22]).[40] Patients with no pain preoperatively were assigned a DW of 0.011 as we considered the presence of the hernia a disability. Then, YLD was calculated by multiplying the DW by the remaining life expectancy at the time of surgery based on WHO Ghana Life Tables for each patient.[41] To determine YLL, the estimated risk of early death was calculated to be 0.00112 per patient-year based on the risk of hernia

Table 1. Items included in the cost analysis.

	Definition	Source of information	Cost calculation method
Medicines and materials			
Medicines	Intraoperative medicines used	- Pharmacy price list	Number of items per standard operation × price per item
Materials	Materials used in surgery	- Procurement and supply departments	Number of items per standard operation × price per item
Staff costs			
Operating room	Mean cost for MD or surgeon and one operating room nurse	- Operative time and hospital payroll	Mean operative time in minutes × salaries per minute
Overhead costs			
Operating room	Overhead costs proportional to operating room space vs hospital size	- Measurement of building size - Hospital budget reports for Volta region	Operating room size proportion × average annual expenditure/average number of operations per day
Patient ward	Overhead costs proportional to ward size vs hospital size	- Measurement of building size - Average hospital budget in Volta region	Ward size proportion × average annual expenditure/number of patients in ward per day
Capital costs			
Operating room	Potential cost if space had been rented as office space in Ho	- Measurement of building size - Average price of leasing office space in Ho	Operating room space in ft^2 × yearly cost per ft^2 of office space in Ho town/365 days/mean number of operations per day
Patient ward	Potential cost if space had been rented as office space in Ho	- Measurement of building size - Average price of leasing office space in Ho	Patient ward space in ft^2 × yearly cost per ft^2 of office space in Ho town/365 days/mean number of operations per day
Equipment	Cost of equipment per operation if all equipment had been bought new	- Procurement and supply department - Electrical equipment office	Equipment cost divided by number of operations equipment (depreciation calculated as cost/365 days × number of years item is depreciated over)

Note. All hospital data were obtained from the Volta Regional Hospital in Ho, Ghana.
MD indicates medical doctor.

complication of 0.0056 and the assumption that the overall risk of death in a groin hernia emergency is 20%.[4,5,14] This number was multiplied by the remaining life expectancy at the time of surgery.[23] Of note, we assumed that the risk of early death after hernia repair was removed based on previous global surgery CEA methodology and hernia surgery literature.[5,14,42] A discount rate of 0.03 was applied in calculating DALYs. The following equations were used for analysis:

DALY = YLD + YLL

YLD = DW × remaining life expectancy at time of surgery

YLL = risk of early death without surgery × remaining life expectancy at time of surgery

Table 2. Translation from IPQ score to disability weights using the GBD 2017.[21,22]

IPQ score	GBD severity category	GBD disability weight
1- No pain	Not applicable	0.011 before surgery 0 after surgery
2- Pain present but could easily be ignored	Mild; does not interfere with daily activities	0.011
3- Pain present could not be ignored, but did not interfere with everyday activities	Mild; does not interfere with daily activities	0.011
4- Pain present could not be ignored, but interferes with concentration on chores and daily activities	Moderate; difficulties with daily activities	0.114
5- Pain present, could not be ignored, interferes with most activities	Moderate; difficulties with daily activities	0.114
6- Pain present could not be ignored, necessitated bed rest	Severe; unable to carry out daily activities	0.324
7- Pain present could not be ignored, prompt medical advice sought	Severe; unable to carry out daily activities	0.324

GBD indicates Global Burden of Disease Study; IPQ, Inguinal Pain Questionnaire.

Table 3. Patient characteristics, costs, and cost-effectiveness of inguinal hernia repair with mesh performed by surgeons and MDs.

Characteristic	Surgeon, n = 109		MD, n = 114		*P* value*
	Mean (SD)	95% CI	Mean (SD)	95% CI	
Age, years	52.5 (17.4)	49.2-55.8	51.3 (16.1)	48.3-54.3	.587
Remaining life expectancy, years	23.3 (13.1)	20.8-25.8	26.2 (25.6)	21.4-30.9	.290
Operative time, minutes	56.1 (24.8)	51.4-60.9	59.1 (17.9)	55.8-62.4	.304
IPQ score preoperative	3.5 (1.9)	3.1-3.9	3.4 (1.8)	3.0-3.7	.615
IPQ score postoperative	1.0 (0.2)	1.0-1.1	1.1 (0.3)	1.0-1.1	.654
DW preoperative	0.14 (0.124)	0.12-0.16	0.12 (0.105)	0.10-0.14	.272
DW postoperative	0.0012 (0.011)	−0.0008 to 0.0033	0.0022 (0.015)	−0.0006 to 0.005	.595
Change in DW preoperative vs postoperative	−0.13 (0.118)	−0.15 to −0.11	−0.12 (0.115)	−0.14 to −0.1	.489
DALYs Averted (discounted)	2.03 (2.06)	1.64-2.43	2.08 (2.27)	1.65-2.50	.890
Cost/DALY averted, USD (discounted)	444.9 (1177.9)	221.2-668.5	278.9 (429.1)	199.3-358.5	.168

CI indicates confidence interval; DALY, disability-adjusted life-year; DW, disability weight; IPQ, Inguinal Pain Questionnaire; MDs, medical doctors; USD, United States dollars.
**P* values are presented for independent sample two-sided Student's *t* test of means.

Incremental cost-effectiveness ratio (ICER) was calculated to measure the economic value of inguinal hernia repair performed by MDs compared with that by surgeons. It is defined by the difference in cost between the 2 interventions, divided by the difference in their effect, which was incremental cost per incremental DALY averted in this analysis.

We defined "very cost-effective" according to the approach suggested by the WHO as costing less than the per capita gross domestic product (GDP) of Ghana per DALY averted and "cost-effective" as < 3 times the per capita GDP of Ghana per DALY averted.[43] For reference, the GDP per capita for Ghana in 2017 was 2074.291 USD.[44]

Sensitivity Analysis

We performed a deterministic sensitivity analysis from the provider's perspective, including halved productivity, doubled and tripled salaries (for surgeons, MDs, and staff), 95% confidence interval (CI) of DWs, +/− 20% variations of standard cost per procedure, and risk of early death. We also analyzed the cost-effectiveness of hernia repair performed for symptomatic cases only (preoperative IPQ score ≥ 2). A probabilistic sensitivity analysis was also conducted by running 1000 simulations through a bootstrapping technique. Based on the results, 95% CI of the ICER was calculated.

Statistical Analysis

Data were analyzed using Microsoft Excel 2016 (Microsoft Corportation) and SPSS (IBM, version 27). Descriptive outcomes are expressed as means with SD and 95% CIs. Independent sample two-sided Student's *t* tests of means were used for cost-effectiveness comparisons between the 2 study groups. $P < .05$ was considered statistically significant.

Results

For the 223 male patients included in the study, the mean age at the time of surgery was 51.8 (SD 16.8) years, and the mean remaining life expectancy was 24.8 (SD 20.5) years (Table 3). There were no statistically significant differences in age or remaining life expectancy between the surgeon and MD groups. The surgeon mean operative time was slightly shorter (56.1, SD 24.8 minutes) than the mean operative time for MDs (59.1, SD 17.9 minutes), but this was not statistically significant ($P = .304$).

The standard cost per procedure was 110.6 USD in the surgeon group and 102.8 USD in the MD group. As shown in Table 3, there was no significant difference in the mean number of DALYs averted or the mean cost per DALY averted between the provider groups. The mean DALYs averted per procedure were 2.03 (95% CI 1.64-2.43) in the surgeon group and 2.08 in the MD group (95% CI 1.65-2.50) ($P = .0890$). The mean cost per DALY averted was 444.9 USD (95% CI 221.2-668.5) in the surgeons group and 278.9 USD (95% CI 199.3-358.5) in the MD group ($P = .168$).

The incremental cost of the operation performed by an MD when compared with a surgeon was −7.8 USD for 0.05 incremental DALY averted (95% bootstrap CI −0.51 to 0.57) (Table 4). The incremental cost per DALY averted (ie, ICER) showed that the MD group dominated the surgeon group (95% bootstrap CI −436.7

Table 4. Incremental cost-effectiveness of inguinal hernia repair with mesh performed by MDs compared with surgeons.

Costs	Surgeon, n = 109	MD, n = 114	95% bootstrap CI
Standard cost per procedure, USD	110.6	102.8	
Incremental cost, USD		−7.80	
DALYs averted (discounted)	2.03	2.08	
Incremental DALY averted (discounted)		0.05	−0.51 to 0.57
ICER, USD (discounted)		Dominates	−436.7 to 454.9

CI indicates confidence interval; DALY, disability-adjusted life-year; ICER, incremental cost-effectiveness ratio; MD, medical doctors; USD, United States dollars.

Table 5. Sensitivity analysis on cost-effectiveness of inguinal hernia repair with mesh performed by surgeons and MDs.

Cost/DALY averted, USD	Surgeon, n = 109		MD, n = 114		*P* value*
	Mean (SD)	95% CI	Mean (SD)	95% CI	
Baseline	444.9 (1177.9)	221.2-668.5	278.9 (429.1)	199.3-358.5	.168
Doubled salaries	545.8 (1445.2)	271.4-820.2	325.9 (501.4)	232.8-418.9	.135
Tripled salaries	646.8 (1712.5)	321.6-971.9	372.9 (573.8)	266.4-479.4	.115
Halved productivity	655.1 (1734.7)	325.8-984.5	420.6 (647.2)	300.5-540.7	.179
Standard cost per procedure (+ 20%)	533.81 (1413.4)	265.5-802.2	334.6 (514.9)	239.1-430.2	.168
Standard cost per procedure (− 20%)	355.9 (942.3)	177.0-534.8	223.1 (343.3)	159.4-286.8	.168
Mortality (+ 20%)	415.1 (997.1)	225.8-604.4	275.2 (421.9)	196.9-353.5	.171
Mortality (− 20%)	487.7 (1453.4)	221.8-763.7	282.6 (436.5)	201.6-363.6	.160
DW for IPQ 6-7 (upper limit)	443.2 (1178.5)	219.4-666.9	277.8 (429.7)	198.1-357.5	.170
DW for IPQ 6-7 (lower limit)	447.8 (1176.8)	224.4-671.3	280.8 (427.9)	201.4-360.2	.165
DW for IPQ 4-5 (upper limit)	435.3 (1180.6)	211.2-659.5	271.0 (432.6)	190.7-351.3	.174
DW for IPQ 4-5 (lower limit)	459.1 (1174.1)	236.2-682.0	290.6 (424.5)	211.8-369.4	.160
DW for IPQ 2-3 (upper limit)	331.4 (1145.1)	114.0-548.8	166.0 (228.2)	123.7-208.3	.141
DW for IPQ 2.3 (lower limit)	698.4 (1345.5)	442.9-953.8	531.1 (875.1)	368.7-693.4	.270
Discount rate (0)	272.2 (451.4)	186.5-357.9	218.9 (380.8)	148.2-289.5	.340
Symptomatic hernia patients (IPQ 2 and above)†	232.0 (984.0)	17.1-446.8	129.7 (234.9)	79.6-179.8	.348

CI indicates confidence interval; DALY, disability-adjusted life-year; DW, disability weight; IPQ, Inguinal Pain Questionnaire; MD, medical doctor; SD, standard deviation; USD, United States dollars.
**P* values are presented for independent sample two-sided Student's *t* test of means.
†There were 87 symptomatic patients in the MD group and 83 symptomatic patients in the surgeon group.

to 454.9) in conducting mesh hernia repair for the study participants.

Table 5 presents the results from the sensitivity analysis of the cost per DALY averted for the operation in each provider group to variations of key parameters. Halved productivity, from a standard of 5 cases per day to 2.5 cases per day, increased the cost per DALY averted by approximately 50%, or to a similar level to the scenario where all salaries were tripled. A significant impact on cost-effectiveness of the operation was seen when asymptomatic patients were excluded from the analysis. For patients with symptomatic hernias, the mean cost per DALY averted was 232.0 (95% CI 17.1-446.8) in the surgeon group and 127.9 (95% CI 79.6-179.8) in the MD group ($P = .348$). For all scenarios, inguinal hernia repair with mesh remained very cost-effective when performed by either provider level in Ghana.

Figure 1 illustrates the sensitivity of the incremental cost per DALY averted (ICER) of the operation performed by MDs compared with surgeons to variations of key parameters. The most significant change was caused by the salary increase, which proportionately lowered the ICER. No discounting and prioritizing patients with symptomatic hernias, on the other hand, raised the ICER by 78% and 45%, respectively. Adjustments of other parameters, such as DWs, standard cost per procedure, risk of early death, and half productivity led to relatively subtle changes to the value. The ICER remained robust in all tested scenarios.

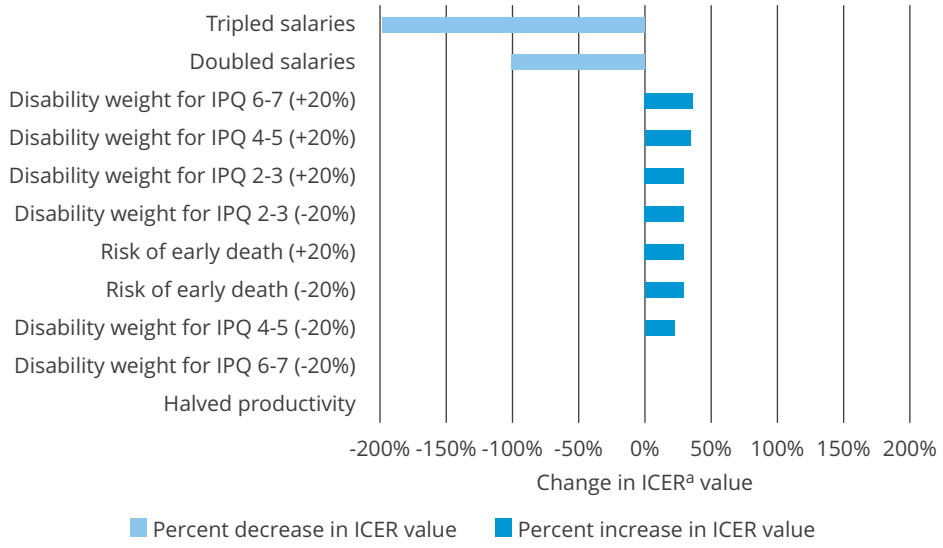
Discussion

We found that elective inguinal hernia repair with commercial mesh performed by Ghanaian surgical care providers on male patients with primary reducible hernias is very cost-effective. Our findings echo the results of previous hernia repair cost-effectiveness analyses conducted in Western Ghana, Uganda, and Ecuador, adding further evidence to support the prioritization of inguinal hernia repair with mesh in the delivery of primary healthcare in LMICs.[11,12,14,45]

Our study adds new knowledge to the global health and global surgery cost-effectiveness literature and is the first of its kind to explore the effect of task-sharing on hernia surgery cost-effectiveness. Previous economic evaluations of surgical task-sharing have shown mixed results. A study from Mozambique found that employing a nonphysician clinician or técnico de cirurgia to perform obstetric surgical care costs one-third as much as the cost involved in employing a specialist in Obstetrics.[46,47] Conversely, a modeling study investigating task-sharing for surgical care in rural Ethiopia conducted by Shrime and colleagues[4] found that, although surgical task-sharing has a significant positive health impact, it does so by increasing costs for already impoverished people. In our study, we found that open mesh repairs performed by both surgeons and MDs were very cost-effective compared with the threshold value of Ghana's GDP per capita. Although the ICER inferred the likely cost-effectiveness of MDs compared with surgeons, the difference in cost per operation between surgeons and MDs was just 7.8 USD, and there were no statistically, financially, or clinically significant differences in effectiveness of the operation between the 2 provider groups. Therefore, task-sharing of inguinal hernia repair with MDs did not result in significant cost saving.

There are several possible explanations for the finding of no significant difference in cost-effectiveness between the 2 provider groups. First, although there was a difference between the salaries of surgeons and MDs, salary represents a relatively small proportion of the total costs of hernia surgery for both types of

Figure 1. Sensitivity analysis on incremental cost-effectiveness of inguinal hernia repair with mesh performed MDs compared with surgeons.



[a]ICER indicates incremental cost-effectiveness ratio; MD, medical doctors.

providers in this study. Because both surgeons and MDs can perform multiple hernia operations per day, the differences in salaries were divided among multiple patients. This study did not include costs relating to the training of healthcare providers. Including training costs would have increased the costs for both cadres, most likely more so for the surgeons compared with the MDs.

Although cost is an important element in the delivery of essential surgery, access to care is also necessary in a functioning surgical system. In Ghana, a nationwide study found that most first-level hospitals did not have a surgeon despite performing a significant number of district-level hernia surgeries.[30,31] Based on the results of the present study, the main benefit of task-sharing between surgeons and MDs is not cost saving. Instead, task-sharing with MDs serves to expand the pool of skilled surgical providers able to provide hernia surgery for the many millions of people living with hernia in Ghana and sub-Saharan Africa. Well-trained MDs are vital members of the Ghanaian surgical workforce, ensuring essential surgical care in district hospitals, especially in rural areas.[30,31]

Our sensitivity analysis shows that productivity appears to be key to maintaining high levels of cost-effectiveness, although it does not seem to have an impact on the ICER between the 2 provider groups. In the context of the study, if high productivity can be ensured, salaries for all surgical providers could be increased while maintaining cost-effectiveness. Increased salaries could motivate surgeons, MDs, and staff to perform the significant volume of hernia surgeries needed to have a public health impact on the burden of disease from hernia in Ghana. In addition, increasing salaries could address challenges with hiring and retaining providers in rural or underserved areas. From the health economics and equity perspectives, patients with symptomatic inguinal hernia should be prioritized over those with asymptomatic hernia in the design of future public health interventions.

To place our study in context, we reviewed the existing literature on inguinal hernia repair cost-effectiveness globally. We found 8 studies conducted in 7 countries, including 3 high-income countries and 4 LMICs.[11,12,14,45,48-51] Several methods of hernia repair were studied, including tissue repair, open mesh repair (mosquito-net and commercial mesh), and laparoscopic repair. Varying measures of cost and cost-effectiveness were used, including cost, DALYs averted, and quality-adjusted life-years gained. Our review of these studies indicates that inguinal hernia repair is cost-effective across a variety of surgical methods and contexts and in countries of all income levels.[11,12,14,45,48-51]

Our study overcomes some limitations found in previous research. Of the 8 studies we reviewed, 2 were analyses of cost data from international surgical missions, which may not accurately reflect the day-to-day delivery of surgical care in LMICs.[11,12] In Shillcutt and colleagues'[11] CEA of an Operation Hernia mission in Ghana, the hernia repair cost-effectiveness was greater than the cost-effectiveness found in our study. Shillcutt's higher cost-effectiveness could be because salary, transportation, and costs of lost wages for the high-income surgeons who participated were not included. In addition, an extremely low-cost mosquito-net mesh was used for hernia repair, which is no longer recommended.[52] In contrast, our study analyzed the cost and cost-effectiveness of hernia repair performed by local providers using locally available materials, including standard commercial mesh, and is therefore more likely to accurately reflect the delivery of surgical care in Ghana. In addition, we used pre- and post-operative pain scores at 1-year to estimate DWs, which would be unlikely to overestimate benefits of inguinal hernia repair.[12]

Our study has limitations, which we present within the context of previously defined guidelines for economic evaluations.[37,53] Similar to other CEAs in LMICs, we used DALYs as our health outcome metric, which can create skewed results for older patients and underestimate treatment benefit. This is particularly important to consider for inguinal hernia, as the incidence of disease increases with age and discounting disability in older patients may be seen as age discrimination.[54] Any patient with symptomatic hernia who is a surgical candidate should be offered repair, regardless of age. Because of our study design, we did not include patients' direct nonmedical costs or indirect costs, and we did not account for possible long-term complications. Although including these data would be unlikely to change our ultimate findings, exploring these costs and long-term complications will be an important area for future research. Although some of our

findings are broadly transferrable to other contexts, including patient health states before and after hernia surgery, costs of materials and medicines and provider salaries are likely more narrowly transferrable to hospitals Ghana's public health system and other similarly resourced settings.[55] Our sensitivity analysis has attempted to account for variations in productivity, hospital costs, and staff salaries, nevertheless there are likely factors we could not account for that would reduce transferability. Finally, our CEA results may not be generalizable to all patients with inguinal hernia, including women, children, and patients with incarcerated or strangulated hernias or to patients undergoing inguinal hernia repair in other settings, including first-level or rural hospitals.

Conclusions

In this CEA, we found that elective inguinal hernia repair with mesh performed by Ghanaian providers on men with primary reducible hernias using locally available materials is very cost-effective, regardless of surgical provider training level. These results combined with our previous task-sharing outcomes study indicate that with adequate training, local surgical care providers, including surgeons and MDs, can perform high-quality elective inguinal hernia repair using mesh with excellent outcomes and high cost-effectiveness in the context of the study in this lower-middle income country.[15] To maximize cost-effectiveness, symptomatic patients should be prioritized over asymptomatic patients and a high level of productivity should be maintained. Policy makers in similarly resourced countries could consider utilizing task-sharing to expand access to inguinal hernia surgery with the caveat that robust training opportunities, oversight, and outcomes monitoring are necessary to ensure patient safety.

Going forward, barriers to widespread availability of mesh inguinal hernia repair in LMICs beyond workforce limitations must be addressed, including access to commercial mesh, infrastructure development, and capacity building for surgical training in mesh technique. As a next step, we are implementing our training program for MDs in first-level hospitals around Ghana and evaluating outcomes. Through this program, we will continue to develop and support supply chains for low-cost commercial mesh and develop resources for essential surgical capacity in Ghana.

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