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ORIGINAL SCIENTIFIC REPORT

Surgery and Obstetric Care are Highly Cost-Effective Interventions in a Sub-Saharan African District Hospital: A Three-Month Single-Institution Study of Surgical Costs and Outcomes

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Abstract

Background The Lancet recently sponsored a commission examining the role of surgery in global health. There is a paucity of published information on the cost-effectiveness of surgery in low- and middle-income countries, a key metric in the prioritisation of limited resources.

Methods All patients undergoing emergency laparotomy, elective and emergency inguinal hernia repair, elective and emergency caesarean section, amputation, fracture manipulation, or fracture fixation over a 3 months period in a single district African hospital were assessed. World Health Organisation global burden of disease (GBD) methodology was used to calculate the disability-adjusted life years (DALYs) saved for each patient (using global and local life expectancy). Fully loaded costs were calculated for each patient's care and providing the overall surgical service. Cost-effectiveness was calculated in year 2012 US$ per DALY saved for each procedure and overall.

Results A total of 428 patients were included, with an overall cost-effectiveness of $10.70 per DALY averted. The cost-effectiveness of individual procedures (global life expectancy) was

Amputation—$17.66
Emergency caesarean section—$7.42
Elective caesarean section—$20.50
Emergency laparotomy—$8.62
Elective hernia repair—$15.26
Emergency hernia repair—$4.36
Fracture/dislocation reduction—$69.03
Fracture/dislocation fixation—$225.89

Conclusions Surgery is a highly cost-effective healthcare measure in the setting of an African district hospital. The presented outcomes demonstrate that surgery is on a par with better-recognised and funded interventions such as HIV anti-retrovirals, malaria prevention and diarrhoea treatment. There are recognised limitations with the GBD methodology used here; however, this remains the best way to investigate the cost-effectiveness of health interventions. This study provides useful information on an, at present, under-studied field.

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Introduction

Surgery is increasingly recognised as a key component of global health, with a recent *Lancet Commission* reporting on the current state and future prospects of global surgery [1–4]. Treatment of infectious diseases is the poster child of global public health, particularly in light of the current Ebola outbreak in West Africa. Surgery, trauma and obstetric complications however form a sizeable proportion of healthcare need in low- and middle-income countries (LMICs), a need that is little recognised let alone met [4].

Contemporary investigation of global health has increasingly focused on tangible measures, such as cost-effectiveness, as a means of targeting limited resources [5]. There is a large and expanding body of literature examining the cost-effectiveness of medical or societal interventions such as HIV medication or mosquito nets, but relatively little examining the role of surgery [6]. It is increasingly recognised that a core provision of basic surgical care can be provided in a sustainable fashion, often by non-physician clinicians and that this may be a cost-effective global health intervention [3, 7, 8].

The importance of surgery was recognised some years ago and yet there remains a paucity of good quality data on cost-effectiveness [9]. Small studies have examined the cost-effectiveness of surgery in hospitals in Cambodia, Sierra Leone, Haiti, Nigeria and Bangladesh, where it compared favourably to interventions in infectious diseases [9–13]. The third edition of Disease Control Priorities, published by the World Bank, discusses the cost-effectiveness of a variety of surgical interventions [14]. It is only able to devote one short paragraph to the topic of emergency general surgery due to the absence of research.

This study is one of very few to utilise WHO-CHOICE guidelines to investigate the cost-effectiveness of surgery and obstetric care in a rural district hospital in Africa [5].

Materials and methods

The setting

St Francis' Hospital is a 350 bed district hospital in Eastern Province, Zambia, providing care to a local population of 200,000 and a tertiary referral population of 1.5 million, some travelling several hundred kilometres for treatment. The 2013 GDP/capita of Zambia was US$1539. The majority of the local population engage in subsistence farming, with relatively little nearby commerce.

Surgical and obstetric care is provided by a staff of several senior specialists supported by junior doctors from Zambia and abroad and a team of medical and clinical officers. Surgery is performed by the most qualified person available, which might be a surgeon, either fully trained or in training, or a suitably trained non-physician clinician. All care is provided free of charge, funded by the Zambian Government, the Church and charitable donations. The hospital has limited access to radiology and laboratory testing and is frequently limited by power cuts.

Emergency surgery is performed as soon as clinically indicated after admission; all other non-elective cases are planned for one of three operating days per week. Elective cases are planned through outpatients then admitted on a set date for surgery. Very few patients undergo day case surgery due to the poor transport links and limited community healthcare.

Study overview

Local hospital approval was granted to undertake this study. Medical data collection and analysis was performed by hospital clinicians, economic data collection and analysis was performed by one author (CR) with expertise in business management and due diligence. All data were stored anonymously on a single password protected computer, no patient sensitive information was removed from the point of care.

Between September and December 2012, admission and outcome data were collected for all patients undergoing one of eight index procedures—amputation, emergency and elective caesarean section, emergency laparotomy, emergency and elective inguinal hernia repair, fracture manipulation and fracture fixation (internal or external). Disability-adjusted life years (DALYs) averted were calculated using World Health Organisation (WHO) [15, 16] methodology and a modification of the methodology initially proposed by Gosselin [11]. Fully loaded costs for all hospital services used were calculated per patient and used to provide a cost per DALY averted in year 2012 US$.

DALY calculations

DALYs averted were calculated as a sum of the years of life lost to the untreated condition (YLL) and years lived with disability due to the untreated condition (YLD). As the actual treatment outcome was available, Gosselin's technique was modified to represent true rather than predicted

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Table 1 Maternal and neonatal disability weights for complications of labour

Indication for caesarean section	Maternal disability weight (lowest and highest estimates)	Neonatal disability weight (lowest and highest estimates)
Obstructed labour	0.11 (0.05–0.15)	1 (0.9–1)
Ruptured uterus	1 (No range)	1 (No range)
Antepartum haemorrhage	0.5 (0.4–0.6)	0.119 (0.05–0.15)
Prolonged first stage	0.05 (0.01–0.1)	0.05 (0.01–0.1)
Transverse lie	0.05 (0.01–0.1)	1 (0.9–1)
Previous caesarean section	0.1 (0.05–0.15)	0.05 (0.01–0.1)
Eclampsia	0.5 (0.4–0.6)	0.5 (0.4–0.6)
Breech primip	0 (No range)	0.05 (0.01–0.1)
Foetal distress	0 (No range)	0.5 (0.4–0.6)
Cord prolapse	0 (No range)	1 (0.9–1)

outcomes [11]. For orthopaedic patients discharged to heal in plaster casts, an appropriate modification was applied to account for the risk of poor long-term outcomes. Where available, the disability weight (DW) of the untreated condition was taken from the 2010 global burden of disease (GBD 2010) study [16], and where not available (i.e. obstetric complications), the DW was taken from peer-reviewed literature or, as a last resort, using an educated estimate between the authors. The range of DWs published for emergency caesarean section was reached by consensus discussion between GR and AJ.

Cost-effectiveness using both global and local life expectancy is presented. The global life expectancy used was that defined by Murray et al. in their methodology for GBD 2010, with a normative life table representing the best attainable life expectancy (86 years in this instance) internationally [17]. Local life expectancy was calculated from the 2012 WHO life tables [18].

For fracture surgery, it was assumed that, untreated, the isolated injury to be treated would not result in death, and hence, YLDs were calculated as the DALYs averted. YLDs were calculated as life expectancy $\times$ actual outcome at discharge (good $= 1$, acceptable $= 0.7$, poor $= 0.3$) $\times$ DW (GBD 2010) $\times$ likelihood of long-term cure (>95 % $= 1$, 50–95 % $= 0.7$, 5–50 % $= 0.3$).

All amputations were carried out for life-threatening conditions, and hence, DALYs averted were calculated as life expectancy $\times$ actual outcome at discharge (alive $= 1$, dead $= 0$) $\times$ (1 $-$ DW for appropriate limb amputation [16]). The reason for calculating the DW averted as 1 $-$ DW for the amputated limb is the assumption that the life has been saved (hence the multiplier of 1), but a disability equal to the amputation has been created (hence the subtraction of the DW).

Caesarean section was carried out for a variety of conditions, and both electively and in an emergency. DALYs averted were calculated as the sum of the maternal and neonatal DALYs averted. Maternal and neonatal disability weightings are shown in Table 1. Maternal DALYs averted were calculated as life expectancy $\times$ maternal DW $\times$ maternal outcome (alive $= 1$, dead $= 0$) [10, 19–22]. Neonatal DALYs were calculated as life expectancy $\times$ neonatal DW $\times$ neonatal outcome (alive $= 1$, dead $= 0$).

All emergency laparotomies and emergency hernia repairs were carried out for immediately life-threatening conditions. Emergency hernia repairs requiring laparotomy and bowel resection were counted in the laparotomy section. For laparotomies, it was assumed that patients were cured if they survived to discharge, and for hernias, a 5 % lifetime risk of recurrence was factored into the calculations [23]. DALYs averted were calculated as life expectancy $\times$ outcome (alive $= 1$, dead $= 0$) $\times$ 0.95 (if an emergency hernia repair).

Patients undergoing elective inguinal hernia repair had their DW calculated as per Kingsnorth et al. [24], modified to give patients with a grade 1 hernia a DW of 0.05 to represent them being symptomatic to the extent of seeking surgical intervention. Paediatric inguinal hernia repairs were given a DW of 0.16 due to their higher risk of incarceration [25]. All hernia DALYs averted were calculated as life expectancy $\times$ DW $\times$ likelihood of long-term cure (assumed to be 0.95 given a 5 % lifetime recurrence rate [23]).

Cost calculations

The fully loaded cost of treating each patient has been calculated and allocated to their clinical outcome. This includes the cost of constructing, outfitting, staffing and maintaining the hospital, as well as all consumables used in their care and their own costs.

Costs were calculated as the sum of the actual goods consumed and a proportion of the hospital overheads. The consumable costs were calculated from drug, fluid, blood

and surgical expendables usage [26, 27]. Pricing was taken directly from the hospital costs where available. Zambia has a centralised, government funded, distribution network for drugs and theatre consumables (i.e. sutures). For these items, the pricing was calculated from the WHO African essential price indicator or online wholesalers [26].

The surgical staff comprised three locally employed consultants (two in obstetrics, one in surgery), two Western registrars working as long-term volunteers (paid a local stipend) and a rotating staff of Zambian junior doctors, licentiates and clinical officers. All nurses were locally trained and paid. Staff costs were calculated as the local outgoings for the hospital. No staff were drawing a salary from home institutions.

As the study did not reflect the entirety of the hospital workload, the remainder of the costs (staff, equipment, buildings, general maintenance and utilities) were calculated for the hospital as a whole and allocated to individual patients as a fraction of outpatient visits, theatre time and length of inpatient stay [28]. All equipment was depreciated as per recommended lifespan and inflation of 3 % per annum added to account for replacement. Costs to the patient and their companions were calculated by a representative survey of inpatients' travel expenditure, daily subsistence and loss of earnings.

All surgical equipment (including anaesthesia equipment, operating table, diathermy machine) were fully costed and depreciated as described above. All implant costs were attributed to the patient being treated.

All costs were converted to year 2012 US$ at the contemporary exchange rate to provide a standard currency for comparison to other studies.

Cost-effectiveness calculation

For each intervention, the summed patient costs were divided by the total number of DALYs averted to give an average cost per DALY in year 2012 US$. This is the recognised measure of cost-effectiveness in WHO-CHOICE methodology [5].

CHEERS statement

The study is published according to the CHEERS statement for health economics studies [29].

Role of the funding source

The lead author was a volunteer at St Francis' hospital supported by a fellowship from the Association of Surgeons in Training UK and Covidien and a grant from the Beit Trust. No external funding was provided for the study.

Results

A total of 428 patients (excluding the babies delivered at caesarean section) underwent at least one of the monitored procedures in the 3-month study period (Table 2). The median age was 25 years, and 65 % of the patients were female.

The DW of the DALYs averted for caesarean section was estimated in discussion between the authors, based on peer-reviewed literature (Table 1). As there is no reported assessment of the incidence of obstetric fistula or death following particular obstetric complications, the DALYs averted, and cost per DALY averted, are published as a range reflecting that uncertainty.

Elective and emergency caesarean section accounted for 48 % of all patients operated on and 67 % of all DALYs averted. Emergency general surgery for life-threatening conditions (laparotomy, amputation and emergency hernia repair) accounted for 17 % of the patients and 27 % of the DALYs averted. Operative orthopaedic trauma (i.e. closed

Table 2 Demographics of study population

Procedure	Number of patients	Gender ratio M:F	Median age (IQR)	Mortality (%)	Median length of inpatient stay (IQR)
Amputation	23	78:22	40 (9–71)	17	14 (0–35)
Emergency caesarean section	196	N/A	24 (13–35)	Maternal—1 Neonatal—11	6 (5–7)
Elective caesarean section	11	N/A	30 (25–35)	Maternal—0 Neonatal—0	7 (6–8)
Emergency laparotomy	44	48:52	35 (10–60)	9	7 (2–12)
Emergency inguinal hernia repair	6	100:0	33 (24–42)	0	3 (0–8)
Elective inguinal hernia repair	16	100:0	15 (0–72)	0	3 (2–4)
Fracture/dislocation reduction	103	71:29	11 (0–32)	0	3 (0–6)
Fracture/dislocation fixation	29	71:29	30 (9–51)	0	9 (1–17)

or open manipulation of fractures, with or without fixation) accounted for 31 % of the patients but only 2.5 % of the DALYs averted. Elective inguinal hernia repair accounted for the remaining 4 % of the patients and 3.5 % of the DALYs averted.

One bed day for inpatient treatment costs $16.73 for a surgical ward and $21 for the maternity ward. One hour of operating theatre time costs $101, which includes staffing and facilities but not surgical equipment or implants, which were separately accounted. The cost of imaging was $4.47 per radiograph, including staffing, equipment and expendables. An outpatient visit was costed at $3.07, including staffing and buildings. The average cost to the patient and their companions per bed day, in terms of lost productivity and travel, was $2.23.

Cost-effectiveness based on global life expectancy

A total of 11,713 (10,133–12,855) DALYs were averted with an overall cost per DALY of $10.70 ($9.75–$12.37). Table 3 demonstrates the broken down cost-effectiveness for individual procedures, ranging from $4 to $226 per DALY averted. Figure 1 shows the relative cost-effectiveness of a range of global health measures relative to the composite figure for surgery in this study as well as the individual interventions, using global life expectancy to calculate DALYs averted.

Cost-effectiveness based on Zambian life expectancy

Using a life table based on year 2012 Zambian life expectancy, a total of 7856 (6791–8633) DALYs were averted, with an overall cost per DALY of $15.96 ($14.52–$18.46). The range of cost-effectiveness of individual procedures, using local life expectancy, is $6 to $337 per DALY averted.

It must be noted that DWs have changed between iterations of the GBD publications, and this study reflects the latest 2010 figures, which vary slightly from those used historically.

Discussion

The interventions assessed in this study form the core of emergency surgical provision required at a district hospital level in LMICs. They could reasonably be undertaken by an appropriately trained General Surgeon with adequate anaesthetic, diagnostic and ward support. Both individually and collectively they are very cost effective using the criteria of the WHO commission on macroeconomics and health (cost/DALY less than GDP/capita). The cost-effectiveness of $10.70/DALY compares extremely favourably to short term surgical missions ($12.88–$362 per DALY), HIV anti-retroviral therapy ($350–$500 per DALY) and bed nets for malaria prevention ($14.20 per DALY) [4, 30, 31]. It is also similar to previously published cost-effectiveness in surgical hospitals in different parts of the world [10–13].

This study is unique in that it has examined costs and outcomes on an individual patient basis for a large number of patients in sub-Saharan Africa. The resulting data give an accurate picture of the cost-effectiveness of providing core surgical services in a district hospital. Most cost-effectiveness analysis is performed using models or population level statistics—whilst high level statistics are useful, studies like this one are needed to clarify the actual practice on the ground, particularly in challenged health services with limited scope for accurate central data collection. The numbers presented here show the magnitude of work performed in busy African district hospitals and provide cost-effectiveness data over an adequate period of time to be meaningful. The numbers of individual procedures vary, with the number of hernia repairs disappointingly low; however, the overall distribution of work is perhaps more

Table 3 Procedural cost-effectiveness

Procedure	Global life-expectancy		Zambian life-expectancy	
	Cost per DALY averted (year 2012 US$)	DALYs averted	Cost per DALY averted (year 2012 US$)	DALYs averted
Amputation	17.66	747	26.92	489
Emergency caesarean section (range reflects range of disability weights)	7.42 (6.49–9.25)	7956 (6376–9098)	11.07 (9.66–13.84)	5329 (4264–6106)
Elective caesarean section	20.50	158	30.61	106
Emergency laparotomy	8.62	2080	12.64	1418
Emergency inguinal hernia repair	4.36	328	6.66	215
Elective Inguinal hernia repair	15.26	154	24.03	98
Fracture/dislocation reduction	69.03	238	98.73	166
Fracture/dislocation fixation	225.89	52	336.78	35

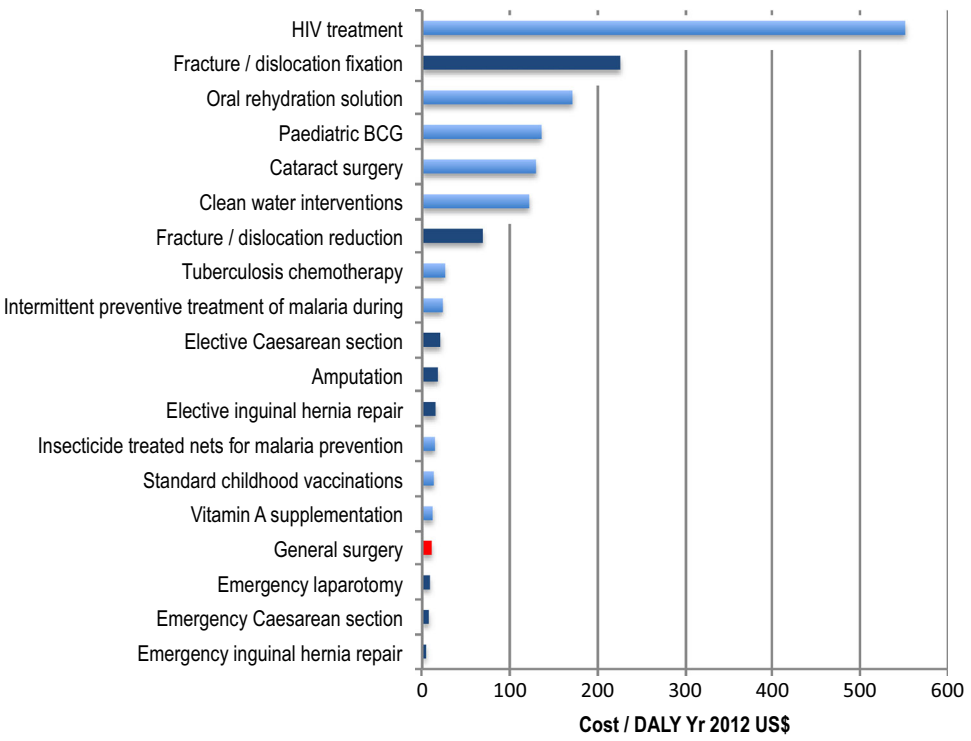

Fig. 1 Cost-effectiveness comparison of public health interventions (global life expectancy data used from this study). *Dark blue* this study. *Light blue* literature. *Red* composite figure for all interventions in this study [14]

interesting to those involved in providing general surgical services across the developing world.

It is worth noting that this type of study has some limitations. A number of assumptions have to be made about the risk of death and disability without surgery, some of which can be extrapolated directly from peer-reviewed resources such as GBD 2010. Unfortunately there is not, at present, a true model of the risks of untreated complications of pregnancy. Many of the DWs applied in the caesarean section portion of the study were derived from literature on the epidemiology and outcomes of pregnancy complications along with expert judgement by the authors. The costs represent running a hospital in Zambia. The true cost will vary across different countries and will be influenced by unaccountable factors, such as local staffing costs, health policy and the opportunity costs to both the patient and the country of providing and seeking health care.

This study was conducted using contemporary DALY techniques and so used an idealised life expectancy [17]. While this reflects best practice in DALY research, it is not indicative of the true local life expectancy, and hence, the outcomes based on local life expectancy have been published in tandem. This study also highlights one of the limitations of DALY methodology, with a relatively small proportion of the DALYs averted arising from orthopaedic trauma, rendering it less cost effective than other interventions. This is despite the large burden of injuries primarily falling on economically active young people, with any disability impacting on earnings and family responsibilities.

It should be noted that most surgery (excluding caesarean section) at St Francis' Hospital is performed under the supervision of a consultant surgeon, which may not be the case in many other units. The outcomes demonstrated in this study represent the experience of the surgical staff and less experienced units may get worse outcomes and so poorer cost-effectiveness.

While this study demonstrates the cost-effectiveness of a surgical institution, it does not address the societal costs of training a surgical workforce, or indeed implementing the much needed development of the infrastructure required to support surgery in the developing world.

Increasingly, it is being recognised that surgical pathology accounts for a significant burden of disease in LMICs, and a current Lancet commission is assessing possible responses [2, 7]. Anecdotally, it has been suggested that surgery is an overly expensive health intervention and money should therefore be prioritised to public health and infectious diseases interventions. It is true that to perform safe surgery a certain minimum facility is required, with basic anaesthetic monitoring, instruments, sutures, dressings and sterilisation facilities. This study demonstrates that not only is this possible within a limited budget, but also that the cost-effectiveness of surgery is at least on a par with better acknowledged and funded global health interventions.

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Compliance with ethical standards

Contributorship GR, CR and CG designed the study. GR, AJ, CG and RB were responsible for clinical data collection and analysis. CR and GR were responsible for financial data collection and analysis. GR wrote the first draft of the manuscript of which all authors had oversight and provided revisions.

Declaration of interests All the authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work. All the authors had full access to the data and manuscript. GR declares that this is an honest, accurate and transparent representation of the study performed. Data sharing: no additional data available.

Ethics approval Ethical review was not required due to the observational nature of the study but prior approval to undertake the study was sought and gained from the senior clinical committee at the hospital.

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