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Original article

Task-sharing or public finance for the expansion of surgical access in rural Ethiopia: an extended cost-effectiveness analysis

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Abstract

Despite a high burden of surgical disease, access to surgical services in low- and middle-income countries is often limited. In line with the World Health Organization's current focus on universal health coverage and equitable access to care, we examined how policies to expand access to surgery in rural Ethiopia would impact health, impoverishment and equity. An extended cost-effectiveness analysis was performed. Deterministic and stochastic models of surgery in rural Ethiopia were constructed, utilizing pooled estimates of costs and probabilities from national surveys and published literature. Model calibration and validation were performed against published estimates, with sensitivity analyses on model assumptions to check for robustness. Outcomes of interest were the number of deaths averted, the number of cases of poverty averted and the number of cases of catastrophic expenditure averted for each policy, divided across wealth quintiles. Health benefits, financial risk protection and equity appear to be in tension in the expansion of access to surgical care in rural Ethiopia. Health benefits from each of the examined policies accrued primarily to the poor. However, without travel vouchers, many policies also induced impoverishment in the poor while providing financial risk protection to the rich, calling into question the equitable distribution of benefits by these policies. Adding travel vouchers removed the impoverishing effects of a policy but decreased the health benefit that could be bought per dollar spent. These results were robust to sensitivity analyses.

Key words: Equity, extended cost-effectiveness analysis, impoverishment, surgery, universal health care

Key Messages

- Per dollar spent, making surgery free at the point of care improves medical impoverishment more than health. It may, however, induce catastrophic spending among the poor.
- Per dollar spent, task sharing has a significant positive impact on health, but does so at the cost of increasing impoverishment in the population.
- Fully addressing both health and financial catastrophe requires addressing the multisectorial nature of health-seeking, with travel vouchers or other "negative user fees".

Introduction

Up to 30% of the global burden of disease is potentially surgical (Shrime *et al.* 2014; 2015). In low- and middle-income countries (LMICs), however, the utilization of surgical services is low, due often to a lack of surgical providers, facilities and equipment, socio-cultural factors, and to the high cost of procedures (Chao *et al.* 2012; Hsia *et al.* 2012; Linden *et al.* 2012; Ilbawi *et al.* 2013; Knowlton *et al.* 2013). A number of policies have been proposed to improve access to surgery, including making surgery free and task-sharing (Kruk *et al.* 2007; Bucagu *et al.* 2012; Jadidfard *et al.* 2012).

In Ethiopia, over 80% of the population of 92 million people lives in rural areas (World Bank 2012; World Health Organization 2012), while most surgeons are located in cities. As a consequence, access to surgery is particularly low (Berhan 2008; Surgical Society of Ethiopia 2013). For example,·3% of women delivered their most recent child by Caesarean section in 2010—20% of women in Addis Ababa, but as few as 0·5% of the poorest women in rural Ethiopia (Central Statistical Agency 2012). While traditional preferences for home delivery play a role, rural women also point to the high cost of care and a lack of providers as reasons for low utilization (Central Statistical Agency 2012; Shiferaw *et al.* 2013): a surgical patient in Ethiopia faces, on average, $204 (1125 Ethiopian Birr) medical costs, as well as up to $611 in non-medical costs (Kifle and Nigatu 2010; United Nations 2014). These non-medical costs—for transportation, food and lodging—can themselves be significant drivers of both impoverishment and decisions to avoid care (Kowalewski *et al.* 2002).

The World Health Organization posits that health systems have three objectives: to improve health, to provide financial protection and to advance fair distribution of the two (World Health Organization 2007). While health policies typically aim at the first, it is unclear whether improving health will necessarily accomplish the latter two. Additionally, standard health economic evaluations of policies have ignored their expected impact on the private economy of households.

This article examines the health and financial risk protection (FRP) benefits of policies to improve surgical access in rural Ethiopia. Using an extended cost-effectiveness analysis (ECEA) framework (Verguet *et al.* 2013a; 2013b; Verguet *et al.* 2014), the following policies are evaluated: (a) universal public financing (UPF), which makes surgery free at the point of care but does not pay for non-medical costs, (b) task sharing (TS) of surgery to non-surgeon providers, and (c) a combination of UPF and TS, (d) UPF with the addition of vouchers (UPF + V), (e) TS + V and (f) UPF + TS + V. Results are examined on average and as they distribute across wealth groups.

Methods

Selection of interventions

A basic package of surgery in rural Ethiopia is defined in Table 1. This package is chosen because the associated thirteen conditions have a large immediate risk (Cobben *et al.* 2000; Neilson *et al.* 2003; Abbas *et al.* 2005; Andersson 2007) of death and, therefore, the interventions have a potentially large individual benefit. For this package, seven policy scenarios are evaluated: keeping surgical delivery at the status quo or implementing any of the six interventions described above. Interventions that include UPF work by transferring the medical cost of an intervention away from patients and onto the public sector. TS models the impact of increasing the supply of surgical providers to the level found in urban Ethiopia. The addition of vouchers transfers the direct *non*-medical costs faced by patients onto the public sector, such that patients face no out-of-pocket (OOP) costs.

Table 1. The 9 surgical procedures and 13 treated conditions included in the model

Procedure	Conditions
Appendectomy	Acute appendicitis, complicated or uncomplicated
Exploratory laparotomy	Abdominal trauma
Caesarean section	Obstructed labour
	Other foetal indications
Salpingectomy	Ectopic pregnancy
Hysterectomy	Post-partum haemorrhage
	Uterine rupture
Vacuum aspiration	Spontaneous abortion
	Post-partum sepsis
Chest tube placement	Thoracic trauma
Amputation	Gangrene
Traction	Uncomplicated long-bone fracture

Model structure, outcomes and data sources

Model structure and outcomes of interest

Using ECEA methodology (Verguet *et al.* 2013; 2014; 2015), we follow a synthetic population of 1 000 000 individuals similar to those in rural Ethiopia and normalized to identically-sized wealth quintiles. ECEA methodology is described in detail in the Supplementary Appendix.

The structure of the model for one surgical condition is given in Figure 1. When facing the modelled condition, a patient will seek care conditional on utilization barriers. If she does so, she experiences perioperative morbidity or mortality, with probabilities as given in Table 2. Total costs, incremental costs, patient-borne costs, non-medical costs and health benefits are calculated. This structure is essentially identical for the other surgical conditions. The model assumes a single-event analytic horizon and, as such, assumes no discounting of costs and/or benefits.

Outcomes of interest were: deaths averted; cases of impoverishment averted; cases of catastrophic expenditure averted; average household cost savings (or 'private expenditure crowded out'); and the incremental governmental costs, above the current status quo, needed to sustain the program.

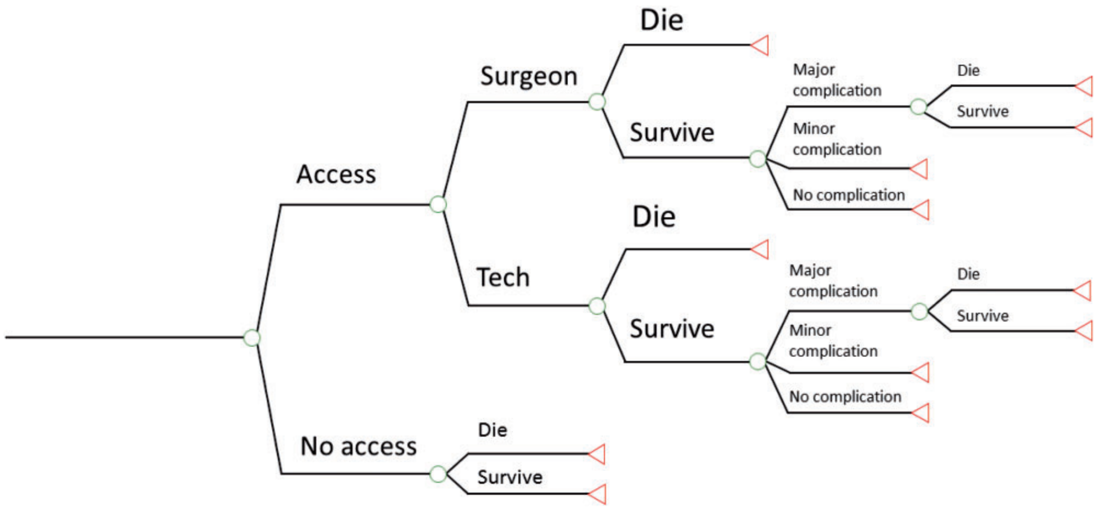

Figure 1. Conditional-probability model for each surgical condition considered. In this model, conditional on having one of the modelled conditions, the patient does or does not have access to surgical care. If she does, she has access from a surgeon or from a task-shifted provider as documented in the text. Outcomes of surgical access are modelled to the right.

Outcomes and utilization data sources and assumptions

Parameter estimates (Tables 2 and 3) draw on national surveys and published studies. When possible, estimates were derived from rural Ethiopia, followed, in order, by estimates from urban Ethiopia, other east African countries, other sub-Saharan African countries and other developing countries; finally, if no other data were available, estimates from the developed world were used. Utilization at baseline is estimated from the 2011 Demographic and Health Survey (Central Statistical Agency 2012). Increases in utilization with decreases in price are modelled based on estimates of own-price elasticity for healthcare services (Reddy and Vandemoortele 1996; Lampietti *et al.* 1999). Increases in utilization with task-sharing were modelled on utilization in Addis Ababa (Central Statistical Agency 2012). More detail on model parameters and assumptions is given in the Appendix.

Costs and assumptions

All costs, including those from outside the Ethiopian context, are adjusted to and reported in international dollars, using purchasing power parity conversions and GDP deflator estimates published by the United Nations and the World Bank (World Bank 2013; United Nations 2014). Methodology for this conversion has been described previously (Schreyer and Koechlin 2002).

Before the introduction of each program, individuals on average pay 34% (19–78%) of medical costs OOP (Vlassoff *et al.* 2012; World Health Organization 2012). Direct non-medical costs to the patient are paid OOP under policies without vouchers, and shift to the public sector with the inclusion of vouchers.

To remain conservative, complication and mortality rates for non-surgeons were assumed to be 1125 times those of surgeons (Gessessew *et al.* 2011). Similarly, the costs of procedures performed by surgeons were assumed to be 147 times higher than those performed by non-surgeons (Vlassoff *et al.* 2008; Alkire *et al.* 2012). In the base-case analysis, the cost of complications was set at $25.50 (Vlassoff *et al.* 2008), and varied stochastically. Costs of scale-up were assumed to be linear for the first 10% increase in utilization, and doubled for any increases above this, so as not to assume constant returns to scale.

Direct costs included medical and non-medical costs. Medical costs included the inpatient costs of surgical delivery (Vlassoff *et al.* 2008; Hu *et al.* 2009; Kifle and Nigatu 2010; Vlassoff *et al.* 2012; Alkire *et al.* 2012). Provider salaries are not explicitly added because this analysis is an incremental analysis and, as such, provider salaries would not change with the implementation of UPF or vouchers. In the base-case analysis, start-up costs for a TS program were included, based on published estimates from Mozambique (Kruk *et al.* 2007) and unpublished estimates from Ethiopia. These included the costs of salaries for the TS providers, training, library buildings, books, computers and travel. We scaled these estimates linearly for differences in population size, and distributed the costs evenly across the population.

Due to likely increased travel costs to centralized providers, non-medical costs were assumed more expensive for care from surgeon than a non-surgeon ($611.66 and $297.45, respectively) (Kifle and Nigatu 2010). Indirect costs (e.g. lost productivity) were considered in sensitivity analyses. Catastrophic expenditure was assumed if patients' expenditure brought their income to either below zero or below 40% of their initial non-health expenditure, following methods described previously (Habicht *et al.* 2006; Reddy *et al.* 2013). More details are provided in the Supplementary Appendix.

Analyses were conducted using the R statistical software (www.r-project.org). Funders had no role in study design, data collection, writing or submission for publication.

Sensitivity and scenario analyses

Scenario analyses were performed on the complication rates generated by task-shifted providers, the inclusion of indirect costs, and the effects of taxation (Supplementary Appendix). Finally, heterogeneity in our estimates was modelled using Monte-Carlo simulation, with 200 distribution draws for every million-person cohort. The 95% posterior credible intervals given in Tables 4 and Supplementary Table S1 were calculated from this simulation

Results

Model contextualization and validation

From the 2011 Ethiopia DHS survey (Central Statistical Agency 2012), we calculated an overall rate of delivery in a medical facility of 16.5%, which is identical to published estimates (Shiferaw *et al.* 2013). The model was then validated against published mortality results from the

Table 2. Condition- and procedure-specific model inputs

	Procedure cost	Perioperative mortality	Mortality, untreated	Major complication rate	Minor complication rate	Prevalence
C-section for obstructed labor	$251.81 (Kifle and Nigatu 2010; Kuper *et al.* 2010)	0.00282 (Gessessew *et al.* 2011)	0.3 (Neilson *et al.* 2003)	0.1094 (Ali 1995)	0.0742 (Ali 1995)	Obstetric conditions: 0·020354 (Thonneau et al. 2002; Worku and Fantahun 2006; Fantu et al. 2010; Singh et al. 2010a,b; Admasu et al. 2011; Gessessew et al. 2011)
VA for uterine Sepsis	$103.07 (Hu *et al.* 2009)	0.022 (Admasu *et al.* 2011)	0.3 (Neilson *et al.* 2003)	0.154 (Igberase and Ebeigbe 2008)	0.22 (Adinma *et al.* 2011)	
Hysterectomy for uterine rupture	$441.02 (Vlassoff *et al.* 2012)	0.214 (Admassu 2004; Alemayehu *et al.* 2013)	0.3 (Neilson *et al.* 2003)	0.14 (Gaym 2002)	0.27 (Gaym 2002)	
Hysterectomy, other causes	$441.02 (Vlassoff *et al.* 2012)	0.02 (Admasu *et al.* 2011)	0.3 (Neilson *et al.* 2003)	0.14 (Gaym 2002)	0.27 (Gaym 2002)	
Salpingectomy	$251.81 (Vlassoff *et al.* 2008; Kifle and Nigatu 2010; Alkire *et al.* 2012; Vlassoff *et al.* 2012)	0.03 (Goyaux *et al.* 2003)	0.75[a]	0.046 (Thonneau *et al.* 2002)	0.046 (Thonneau *et al.* 2002)	
VA for other causes	$103.07 (Vlassoff *et al.* 2009)	0.022 (Admasu *et al.* 2011)	0.3 (Neilson *et al.* 2003)	0.154 (Igberase and Ebeigbe 2008)	0.22 (Adinma *et al.* 2011)	
C-section for other causes	$251.81 (Vlassoff *et al.* 2008; 2012; Kifle and Nigatu 2010; Alkire *et al.* 2012)	0.00282 (Gessessew *et al.* 2011)	0.3 (Neilson *et al.* 2003)	0.1094 (Ali 1995)	0.0742 (Ali 1995)	
Appendectomy	$301.29 (Kifle and Nigatu 2010)	0.012 (Deneke and Tadesse 2001)	0.7 (Anderson *et al.* 2007)	0.0354 (Mawalla *et al.* 2011)	0.14 (Sohn *et al.* 2002; Razavi *et al.* 2005)	Appendicitis: 0.0003 (Andersson 2007; World Health Organization 2008; Groen *et al.* 2012)
Exploratory laparotomy	$393.81 (Kifle and Nigatu 2010)	0.133 (Demissie 2001)	0.923 (Cobben *et al.* 2000)	0.5 (Okeny *et al.* 2011)	0.242 (Ussiri *et al.* 2005; Okeny *et al.* 2011)	Traumatic conditions: 0.06285 (Hailu 2000; Groen *et al.* 2012)
Traction	$352.43 (Kifle and Nigatu 2010)	0[a]	0.06 (Abbas and Archibald 2005)	0.2 (Thomas and Meggitt 1981)	0.0667 (Thomas and Meggitt 1981)	
Chest tube placement	$393.81 (Kifle and Nigatu 2010)	0.16 (Hailu 2000)	1.00[a]	0.105 (Hailu 2000)	0.263 (Hailu 2000)	
Amputation	$352.43 (Kifle and Nigatu 2010)	0.29 (Gulam-Abbas *et al.* 2002)	0.75 (Abbas and Archibald 2005)	0.086 (Harris *et al.* 2009)	0.248 (Harris *et al.* 2009)	

VA, vacuum aspiration.
[a]Assumption.

Table 3. Estimated surgical access under each scenario

Wealth Quintile	Status Quo (Central Statistical Agency 2012)	UPF (Reddy and Vandemoortele 1996; Lampietti *et al.* 1999)	UPF + V (Reddy and Vandemoortele 1996; Lampietti *et al.* 1999)	TS (Central Statistical Agency 2012)	UPF + TS (Central Statistical Agency 2012; Reddy and Vandemoortele 1996; Lampietti *et al.* 1999)	UPF + TS + V (Central Statistical Agency 2012; Reddy and Vandemoortele 1996; Lampietti *et al.* 1999)	TS + V (Central Statistical Agency 2012; Reddy and Vandemoortele 1996; Lampietti *et al.* 1999)
Obstetric conditions							
Poorest	0.03	0.05	0.11	0.21	0.24	0.29	0.26
Poor	0.06	0.08	0.11	0.31	0.32	0.35	0.34
Middle	0.09	0.11	0.13	0.40	0.41	0.44	0.42
Rich	0.13	0.14	0.16	0.50	0.51	0.52	0.51
Richest	0.19	0.19	0.20	0.69	0.69	0.69	0.69
Non-obstetric conditions							
Poorest	0.34	0.37	0.42	0.53	0.56	0.61	0.57
Poor	0.42	0.44	0.47	0.59	0.61	0.64	0.62
Middle	0.50	0.51	0.53	0.66	0.67	0.69	0.68
Rich	0.57	0.58	0.60	0.72	0.73	0.75	0.74
Richest	0.64	0.65	0.65	0.79	0.79	0.79	0.79

See text for details and Supplementary Appendix for underlying assumptions. UPF, universal public finance; TS, task sharing; V, vouchers.

World Bank, UNFPA, UNICEF and World Health Organization estimates. Model estimates of 9112 maternal deaths per year in Ethiopia were consistent with estimates of 9000 (UNICEF, UNFPA, World Bank 2012) and translate to a predicted maternal mortality ratio of 368 deaths per 100 000 live births. This is also consistent with World Bank estimates of 350 (World Bank). The model predicted 0.62 deaths per 1000 from traumatic conditions and 0.012 deaths per 1000 from appendicitis, consistent with World Bank estimates (0.61 and 0.012, respectively) (World Health Organization 2013).

Base-case analysis, without travel vouchers

Health impacts

Health benefits, measured in deaths averted, nominally and per $100 000 spent, are shown in Tables 4 and Supplementary Table S1. Per million people per year in rural Ethiopia, UPF averted 23 deaths, at a cost of $945 000 (2 averted deaths per $100 000 spent, or $50 000/death averted). TS was predicted to avert 253 deaths per million per year in rural Ethiopia, at a cost of $401 000 (64 averted deaths per $100 000, or $1500/death averted). Finally, UPF + TS was predicted to cost the system $2 354 000 per million people per year, and to avert 289 deaths, for a total of 12 deaths averted per $100 000 spent ($8300/death).

Health benefits were not distributed evenly across wealth quintiles. The primary beneficiaries of UPF were the poorest. Under TS, health benefits accrued primarily to the rich. The combination of the two policies maintained a gradient similar to that seen in UPF, but with additional health benefits accruing to the richest quintile.

Financial risk protection

Poverty cases averted. Without vouchers, only UPF was financially risk protective effects. Task sharing *induced* impoverishment on average, and the addition of UPF incompletely mitigated this impoverishment (Tables 4 and Supplementary Table S1). UPF averted 361 cases of poverty per million population, amounting to approximately 38 cases for every $100 000 spent. Poverty was, however, created in the poorest wealth quintiles. The rich and richest patients alone saw a financial benefit.

TS created 578 cases of poverty per million in the population, or approximately 145 cases created for every $100 000 spent. No impoverishment was averted, and most impoverishment accrued to the poor. Finally, UPF + TS created 231 cases of poverty, or 10 cases per $100 000 spent. The distribution of financial risk protection was similar to that seen in UPF.

Health and financial benefits with vouchers

When non-medical costs of care-seeking were transferred away from patients, overall health benefits increased. However, because these interventions are more expensive, fewer health benefits could be bought per dollar. In contrast, these vouchers bought significantly more financial risk protection.

UPF + V averted only 1 death per $100 000 spent, but averted 48 cases of poverty ($2000/case of poverty averted). TS + V averted 9 deaths per $100 000 ($11 000/death averted) but created 19 deaths per $100 000. UPF + TS + V averted 3 deaths and 27 cases of poverty per $100 000 ($33 000/death and $3700/case of poverty).

Distributionally, financial risk protection, where it occurred, continued to accrue primarily to the richer quintiles, while health benefits accrued to the poorest. A comparison of the health benefits and the financial risk protection benefits for each policy is provided in Figure 2, and the distributional impacts are shown in Figure 3.

Crowdout of private expenditure by each policy is given in Table 4. Heterogeneity in model estimates is shown in Figure 4; the 95% posterior credible intervals are given in Tables 4 and Supplementary Table S1.

Discussion

Using an ECEA framework (Verguet *et al.* 2013a; 2013b; 2014), this article examines the health and financial risk-protection (FRP) benefits of six policies to increase surgical access in rural Ethiopia. The results of this analysis explicitly illustrate tradeoffs between health and financial risk protection in the delivery of surgery, and makes clear the equitable—or inequitable—distribution of benefits derived from each policy. Although UPF provides both health and FRP, it leans heavily toward the latter. Conversely, TS buys a lot of health per dollar, but does so at the cost of an increase in impoverishment. Adding UPF to TS mitigates this impoverishment, but only partially; it is not until vouchers that cover the non-medical costs of care are added to UPF that

Table 4. Summary *results per million population*

		Wealth Quintile					
		Poorest	Poor	Middle	Rich	Richest	Overall
Deaths averted per $100,000 spent	UPF (no vouchers)	6 (−24 to 36)	2 (−24 to 32)	3 (−27 to 28)	2 (−16 to 27)	1 (−16 to 16)	2 (−9 to 14)
	UPF with vouchers	3 (−3 to 8)	1 (−4 to 6)	1 (−3 to 5)	1 (−3 to 4)	0 (−3 to 3)	1 (−1 to 3)
	Task sharing	60 (6 to 125)	64 (7 to 136)	64 (16 to 124)	69 (13 to 137)	71 (16 to 146)	64 (37 to 92)
	UPF + task sharing	16 (5 to 28)	14 (2 to 25)	13 (3 to 23)	11 (3 to 19)	10 (3 to 16)	12 (8 to 17)
	UPF + task sharing + vouchers	5 (2 to 8)	4 (2 to 6)	3 (1 to 5)	3 (1 to 5)	2 (1 to 4)	3 (2 to 4)
	Task sharing + vouchers	12 (4 to 20)	10 (2 to 18)	9 (2 to 16)	8 (2 to 14)	6 (1 to 11)	9 (6 to 12)
Cases of impoverishment averted per $100,000 spent	UPF (no vouchers)	0 (0 to 0)	−23 (−78 to 26)	−23 (−79 to 36)	212 (181 to 249)	0 (0 to 0)	38 (24 to 53)
	UPF with vouchers	0 (0 to 0)	87 (80 to 95)	123 (115 to 133)	38 (34 to 43)	0 (0 to 0)	48 (46 to 50)
	Task sharing	0 (0 to 0)	−439 (−560 to − 346)	−274 (−389 to − 211)	−3 (−8 to 0)	0 (−2 to 0)	−145 (−169 to −124)
	UPF + task sharing	0 (0 to 0)	−95 (−121 to −72)	−56 (−79 to −29)	86 (75–98)	0 (0–0)	−10 (−16 to −3)
	UPF + task sharing + vouchers	0 (0 to 0)	49 (44 to 53)	69 (65 to 75)	22 (20 to 24)	0 (0 to 0)	27 (26 to 28)
	Task sharing + vouchers	0 (0 to 0)	−64 (−71 to −56)	0 (0 to 0)	0 (−1 to 0)	0 (0 to 0)	−12 (−13 to −10)
Private expenditure crowded out	UPF (no vouchers)	$0.76 ($0.68 to $0.84)	$0.83 ($0.73 to $0.94)	$0.94 ($0.82 to $1.05)	$1.05 ($0.9 to $1.21)	$1.15 ($1.01 to $1.28)	$4.72 ($4.42 to $4.97)
	UPF with vouchers	$4.56 ($4.36 to $4.77)	$4.89 ($4.65 to $5.12)	$5.44 ($5.15 to $5.7)	$6.09 ($5.84 to $6.38)	$6.59 ($6.2 to $6.95)	$27.57 ($26.98 to $28.28)
	Task sharing	$0.44 ($0.36 to $0.51)	$0.42 ($0.33 to $0.51)	$0.40 ($0.28 to $0.5)	$0.38 ($0.27 to $0.5)	$0.37 ($0.24 to $0.49)	$2.00 ($1.78 to $2.25)
	UPF + task sharing	$1.99 ($1.86 to $2.11)	$2.14 ($2 to $2.3)	$2.34 ($2.18 to $2.5)	$2.55 ($2.37 to $2.73)	$2.75 ($2.54 to $2.93)	$11.77 ($11.36 to $12.1)
	UPF + task sharing + vouchers	$7.97 ($7.64 to $8.31)	$8.68 ($8.33 to $9.06)	$9.63 ($9.15 to $10.04)	$10.65 ($10.17 to $11.14)	$11.59 ($11.1 to $12.11)	$48.52 ($47.62 to $49.57)
	Task sharing + vouchers	$2.61 ($2.47 to $2.74)	$2.89 ($2.72 to $3.05)	$3.19 ($3 to $3.38)	$3.5 ($3.3 to $3.74)	$3.82 ($3.59 to $4.08)	$16 ($15.67 to $16.45)
Incremental system cost, in thousands	UPF (no vouchers)	$151 ($136 to $168)	$166 ($145 to $187)	$187 ($165 to $210)	$210 ($179 to $241)	$230 ($202 to $257)	$944 ($884 to $993)
	UPF with vouchers	$912 ($872 to $954)	$979 ($930 to $1023)	$1087 ($1031 to $1141)	$1218 ($1168 to $1276)	$1319 ($1240 to $1391)	$5515 ($5395 to $5657)
	Task sharing	$87 ($73 to $102)	$83 ($66 to $103)	$80 ($56 to $100)	$76 ($54 to $99)	$73 ($49 to $99)	$400 ($355 to $451)
	UPF + task sharing	$398 ($372 to $422)	$429 ($400 to $459)	$467 ($436 to $499)	$510 ($473 to $546)	$549 ($509 to $587)	$2353 ($2273 to $2420)
	UPF + task sharing + vouchers	$1594 ($1528 to $1662)	$1736 ($1666 to $1812)	$1927 ($1831 to $2009)	$2129 ($2034 to $2228)	$2319 ($2221 to $2422)	$9705 ($9524 to $9915)
	Task sharing + vouchers	$522 ($494 to $547)	$577 ($544 to $609)	$637 ($600 to $676)	$701 ($661 to $749)	$763 ($717 to $815)	$3200 ($3134 to $3291)

Health gains, financial risk protection (measured in cases of poverty averted) and costs for UPF (with and without vouchers), task sharing and task sharing combined with UPF (with and without vouchers) for the modelled surgical interventions in rural Ethiopia. Health and financial risk protection benefits are measured per $100 000 spent. Note that negative numbers of cases of poverty averted represent cases of impoverishment created by the policy. See text and Table 1 for included surgical conditions. Numbers are rounded to the nearest whole and the parentheses represent the 95% posterior credible interval of values.

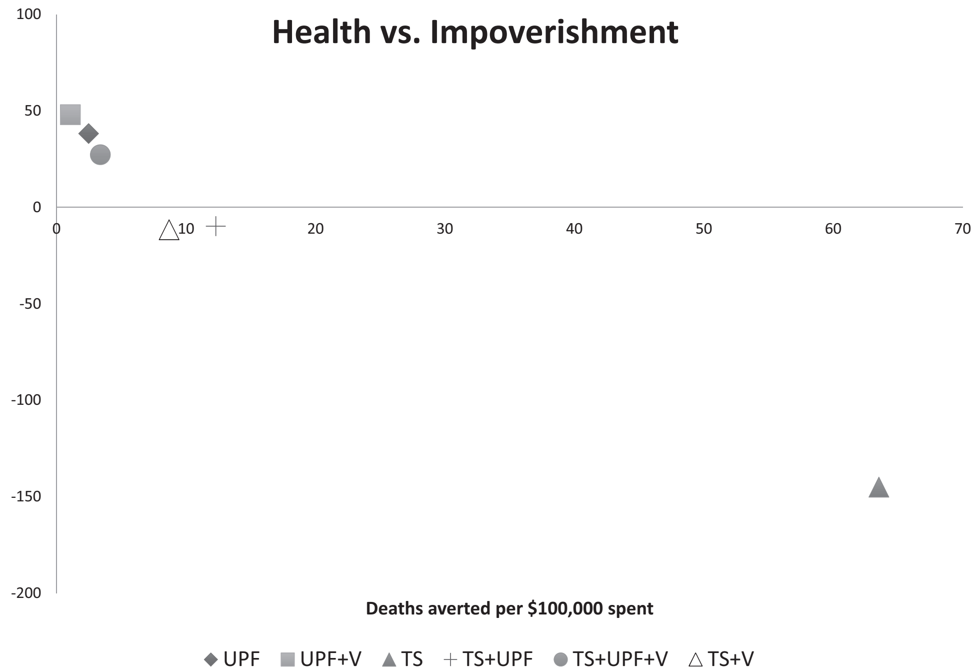

Figure 2. Health protection versus financial risk protection per $100 000 spent, by policy (see text for details). Note that many policies create cases of poverty, driven, in large part, by direct non-medical costs, which are averted by the introduction of vouchers. UPF , universal public financing.

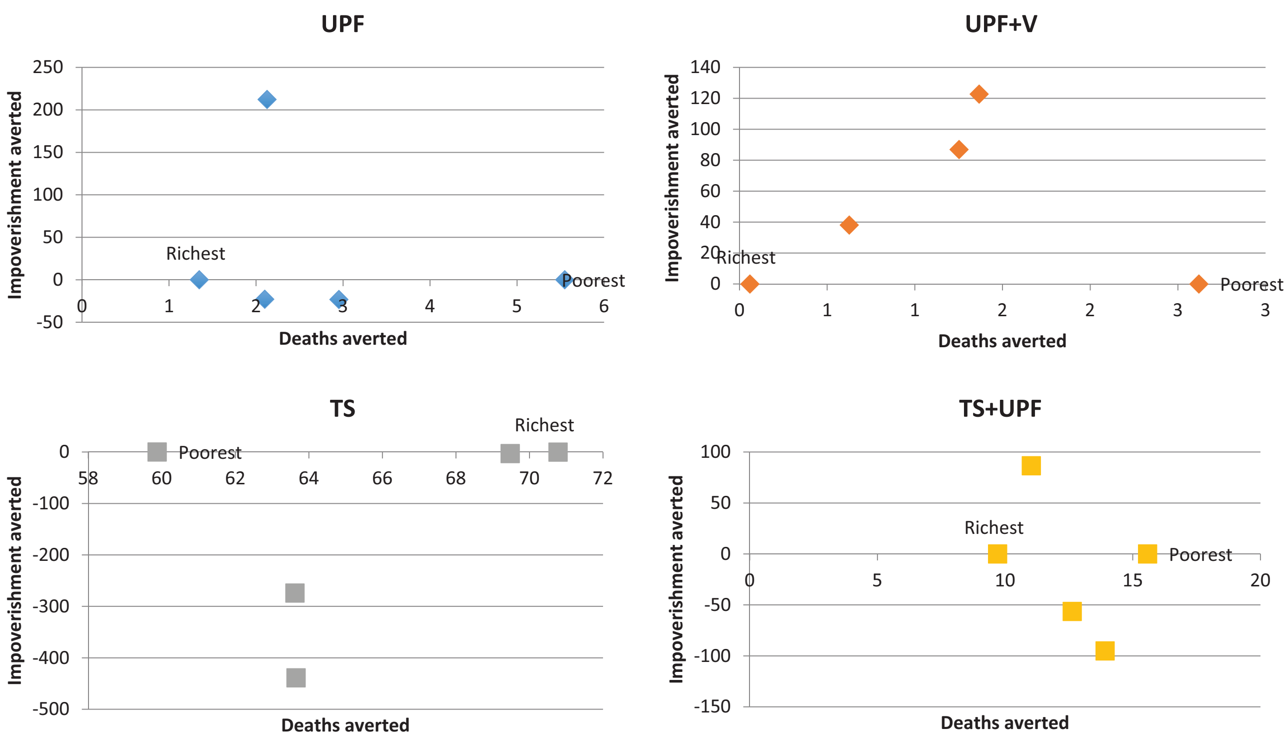

Figure 3. Distribution of health benefits and cases of poverty averted, per $100 000 spent, for each policy across wealth quintiles. Negative numbers of cases of poverty averted are poverty created. UPF, universal public financing; TS, task sharing; V, vouchers.

impoverishment of the poorer segments of rural Ethiopia ceases and the distribution of benefits begins to appear equitable.

While surgical services in Addis Ababa approximate those offered in many higher-income countries (Cadotte *et al.* 2010), care in rural Ethiopia is sparse (World Health Organization 2008). Because of a lack of providers and a high cost (Berhan 2008; Surgical Society of Ethiopia 2013), many surgical conditions go untreated, enlarging the burden of surgical disease in this country.

Universal health coverage is a focus of the World Health Organization (World Health Organization 2013). Both UPF and TS

Figure 4. Heterogeneity in results for each of the six policies. Note that negative cases of impoverishment averted corresponds to cases of impoverishment created; similarly for negative numbers of deaths averted.

have been proposed, for interventions ranging from rotavirus vaccination (Verguet *et al.* 2013), to dental services (Jadidfard *et al.* 2012) to emergency obstetric care (Kruk *et al.* 2007; Scott and Campbell 2011; Bucagu *et al.* 2012; Ejembi *et al.* 2013; Sitrin *et al.* 2013). In Ethiopia itself, task shifting is used to extend the treatment options for HIV patients (Johns *et al.* 2014) and to provide comprehensive emergency obstetric care (Gessessew *et al.* 2011). The Ministry of Health of Ethiopia has also set for itself a goal of training 800 emergency surgical officers by the end of 2015 (Ethiopia MoHo 2015). Meanwhile, although policies exist for the removal of user fees for maternity care, their actual implementation is tenuous (McKinnon *et al.* 2014).

Unlike many global health interventions, however, surgery is a relatively nebulous service, whose borders are indistinct. As a result, it is often provided by disparate, poorly organized platforms (Shrime *et al.* 2014). To facilitate analysis, a bundle of surgical procedures for thirteen conditions was defined and a model built based on data from nationwide surveys and the published literature (Central Statistical Agency 2012). This model proved well-calibrated to current health outcomes in Ethiopia (Shiferaw *et al.* 2013).

The counterintuitive increase in impoverishment by some policies is due to the fact that, while demand for surgical services is induced by some policies, these services are not always free, and patients still have to pay for the non-medical costs of obtaining care. For many patients, these prove catastrophic (Kowalewski *et al.* 2002). Note, however, that because the measure of poverty used in this paper is a count of the number of individuals pushed below the national poverty line, the poorest quintile cannot be “impoverished” by any policy. This is artifactual—25% of Ethiopia lives below the national poverty line; none of the poorest 20% can, by definition, be pushed below it. Catastrophic expenditure, shown in the Supplementary Appendix, unmasks the worsening of impoverishment in the poorest quintile.

There are limitations to this analysis. As with all models, ours is limited by data availability. The costs of a task-shifting program, for example, come from a study in Mozambique (Kruk *et al.* 2007) and had to be scaled to the Ethiopian context. Additionally, we did not have enough data to model the entirety of the referral network. Although focusing on rural Ethiopia allows for differences in care delays between Addis and the rest of the country to be mitigated, it remains true that none of the policies are likely to address delays in getting to care, although, by decreasing barriers, they may address delays in *deciding* to seek care.

We employ a head-count approach to measuring impoverishment, which is often employed (Habicht *et al.* 2006; Garg and Karan 2009; Honda *et al.* 2011; Niens *et al.* 2012). Some authors, however, suggest that a movable threshold (Ataguba *et al.* 2012), or measures of depth of poverty (Garg and Karan 2009) are more appropriate. We model the former in the Supplementary Appendix and the distributional patterns of health and financial risk protective benefits remain essentially unchanged. None of these methods measures the financial burden of a lack of access, however. That is, were a bread-winner to suffer a catastrophic health event, her death may throw an entire household into poverty. This is not explicitly addressed in our current analysis, and is left to future inquiry. Finally, due to the limitations in data availability, this model is forced to assume that existing surgeons can handle the added demand generated by UPF. However, the increased demand from UPF is small (see Table 2); resulting error is not expected to be large.

This analysis, despite its weaknesses, both demonstrates the strengths of ECEAs and applies them, for the first time, to a package of surgical interventions. Since the first proposal of ECEAs by Verguet and colleagues, ECEAs have been employed to evaluate multiple policy and regulatory instruments (Verguet *et al.* 2013a; 2013b; 2014; Watkins *et al.* 2015). This article applies these methodologies to surgical systems. By extending traditional CEA methodology toward policy analysis (as opposed to technology assessment), by incorporating the joint outcomes of health and impoverishment and by making explicit the implementation costs of a surgical platform, the potential impoverishment of some proposed policies, and the distributional equity of health policies, this paper highlights the significant tradeoffs inherent in policies for increasing access to surgical care in LMICs. Of note, these are not dissimilar from those seen in developed countries (Baicker *et al.* 2013). While other authors have proposed multi-criteria decision analytic techniques (Youngkong *et al.* 2012), and while other studies have looked at the role of individual surgical interventions in the alleviation of impoverishment (Kuper *et al.* 2010), this is the first article to allow for systematic policy analysis around surgery, with a specific focus on equity and impoverishment, two of the main objectives of health systems (World Health Organization 2007).

The distribution of benefits seen in this article is initially counterintuitive. UPF appears primarily to improve financial risk protection among the richer segments of the rural Ethiopian population; the small benefits it has on health, on the other hand, accrue to the poorest. Conversely, task-sharing creates cases of poverty while averting deaths across the entire population; the latter benefit primarily accrues to the richest, while the former harm accrues to the poorest.

Because these are counterintuitive findings, the model was tested with in multiple scenario analyses, including widening the complication rates between TS providers and surgeons, including indirect costs, and modelling the effect of taxation. Although the magnitude of the benefits bought per dollar changes with these sensitivity analyses, the changes are small. More importantly, except in the case of taxation, the distribution of the benefits across wealth quintiles is robust to these sensitivity analyses.

How one decides among the modelled policies remains a matter of further research, patient-preference analyses, political debates and ethical analyses. Making normative statements about these policies and their potential unintended consequences on income inequality is not the goal of this paper. Instead, we present this analysis to facilitate open, fair, and well-informed deliberative processes for making these decisions.

Conclusion

This article is the first to examine, simultaneously, the health and financial benefits of policies for improving surgical access in a developing-world context. It highlights tensions between the two and makes explicit their distributional patterns across wealth quintiles. Task sharing appears simultaneously to improve the health of rural Ethiopia but to put the poorest at risk of impoverishment. On the other hand, making surgery free protects against impoverishment in the rich; health benefits and impoverishment both accrue to the poor. The distribution of benefits is most equitable, however, when non-medical costs of care, such as transportation, food and lodging, are no longer shouldered by patients. Further research is warranted to refine how to choose among these disparate policy benefits.

Supplementary data

Supplementary data are available at *HEAPOL* online.

Conflict of interest statement. None declared.

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