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Economic Case for Scale-up of the WHO Surgical Safety Checklist at the National Level in Sub-Saharan Africa

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Objectives: To evaluate the economic case for nationwide scale-up of the World Health Organization (WHO) Surgical Safety Checklist using cost-effectiveness and benefit-cost analyses.

Background: The Checklist improves surgical outcomes but the economic case for widespread use remains uncertain. For perioperative quality improvement interventions to compete successfully against other worthwhile health and nonhealth interventions for limited government resources they must demonstrate cost-effectiveness and positive societal benefit.

Methods: Using data from 3 countries, we estimated the benefits as the total years of life lost (YLL) due to postoperative mortality averted over a 3 year period; converted the benefits to dollar equivalent values using estimates of the economic value of an additional year of life expectancy; estimated total implementation costs; and determined incremental cost-effectiveness ratio (ICER) and benefit-cost ratio (BCR). Costs are reported in international dollars using Word Bank purchasing power parity conversion factors at 2016 price-levels.

Results: In Benin, Cameroon, and Madagascar ICERs were: $31, $138, and $118 per additional YLL averted; and BCRs were 62, 29, and 9, respectively. Sensitivity analysis demonstrated that the associated mortality reduction and increased usage due to Checklist scale-up would need to deviate approximately 10-fold from published data to change our main interpretations.

Conclusions: According to WHO criteria, Checklist scale-up is considered ''very cost-effective'' and for every $ 1 spent the potential return on investment is $9 to $62. These results compare favorably with other health and nonhealth interventions and support the economic argument for investing in Checklist scale-up as part of a national strategy for improving surgical outcomes.

Keywords: anesthesia, cost-benefit, cost-effectiveness, economic analysis, global health, patient safety, return on investment, surgery, WHO surgical safety checklist

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Universal health coverage (UHC), with a focus on increased access to care, improved quality of care, and greater financial risk protection, aims to save lives and prevent disability, and is one of the over-arching objectives of the Sustainable Development Goals era. Surgical care is a key part of UHC because surgical disease accounts for an estimated 33% of the global burden of disease.[1] However, in the face of limited finances, if Ministries of Health are to achieve UCH, they must make choices about individual health sector priorities. Shiffman et al,[2] identified that policy-makers are influenced by both subjective and objective criteria including the cost and cost-effectiveness of an intervention. Economic evaluations, therefore, play a key role in the decision-making process and have been used to guide a variety of global health policy interventions,[3] including the economic argument for surgery as a crucial part of UHC in low- and middle-income countries (LMICs).[4–8]

Globally, 5 billion people lack access to safe, affordable and timely surgical care,[9] and recent estimates show that more people are dying from lack of *high-quality* health care than lack of *access*.[10] Sustainable interventions that improve care quality and can be applied at scale are urgently needed. In the realm of surgical care, the World Health Organization (WHO) Surgical Safety Checklist is an intervention consistently shown to reduce mortality and morbidity after surgery by 23% to 43%.[11,12] Utilization of the Checklist in low resource settings is, however, not widespread and its economic impact remains unknown. Checklist use with adult patients from countries with middle or low Human Development Index is reported as 47% to 57%[13,14] and in children as 36% to 48%[15] – compared to rates of 84% and 94% for adults and children, respectively, in high Human Development Index countries. A systematic review of Checklist implementation in LMICs, identified 47 studies of which none reported any cost implications or whether investment of effort in implementing the Checklist into routine practice was a cost-effective use of resources.[16] Therefore, although there is a clear clinical need to scale-up Checklist implementation in LMICs, the question for Ministries of Health remains: will the effort required be a cost-effective use of limited resources and provide a net positive economic benefit to LMIC societies?

This study evaluates the economic case for Checklist scale-up in 3 sub-Saharan African countries: Benin, Cameroon and Madagascar.

METHODS

Study Design

This was a retrospective economic evaluation using data from Checklist scale-up in Benin,[17] Cameroon,[18] and Madagascar.[19,20] We utilized 2 different methodological approaches: first, a cost-effectiveness analysis (CEA) of implementation in each country, reporting an estimate of the incremental cost of saving one additional year of life within the population receiving surgery [the incremental cost-effectiveness ratio (ICER)][21,22]; and secondly, a benefit-cost analysis (BCA),[22,23] translating the reduction in years of life lost into a dollar equivalent value and subsequently reporting the dollar benefit-to-cost ratio (BCR) for each country.

Sample and Setting

The nongovernmental organization Mercy Ships,[24] in collaboration with the respective Ministries of Health, carried out the Checklist scale-up. Country selection was pragmatic, based on Mercy Ships field-service operations for three consecutive years (2014 – 2017), although a recent systematic review showed that this is the only published data available on nationwide checklist implementation in sub-Saharan Africa.[16] The only other data on nationwide checklist implementation in LMICs is a qualitative study on nursing and surgical perceptions of checklist implementation in Thailand. The total number of hospital facilities' undergoing Checklist implementation was 83 (36, 26, and 21 for Benin, Cameroon, and Madagascar, respectively).[17–20]

In each country scale-up occurred over a ten-month period supported by a multi-component implementation strategy, grounded on implementation theory and stakeholder engagement. Implementation activities included: multidisciplinary training and education, interactive assistance, clinician support, and adaptation of the Checklist to the local context. In all countries Checklist scale-up was successful both in immediate and longitudinal (12–24 months) evaluation post-implementation. Detailed reports of these nationwide implementations have been published recently.[17–20]

Economic Evaluation

Cost-Effectiveness Analysis

We estimated the ''years of life lost'' (YLL) that would be averted due to reducing postoperative mortality through nationwide Checklist implementation. We then evaluated the total dollar cost of Checklist implementation activities that supported scale-up in each country and used this to determine the ICER of Checklist scale-up (total cost divided by the additional YLL that would be avoided). Although data on total surgical volume were available, we lacked data on specific surgical procedures undertaken so we were unable to calculate the effect of the Checklist on disability outcomes for surgical patients who survive. This prevents expression of our results as disability-adjusted life years (DALYs) avoided, a measure commonly used in economic evaluation and burden of disease assessment.[25] However, as the YLL measure forms the survival component of the DALY it provides a conservative measure of Checklist impact. To evaluate whether scale-up amounted to a cost-effective use of resource we compare the estimated ICER for each country against the thresholds used by WHO to assess health program value for money.[26]

Benefit-cost Analysis

We monetized the estimated YLL averted to enable estimation of a BCR, the dollar value of the total YLL averted (ie, years of life saved) divided by the total cost of scale-up. This provides a more direct assessment of whether the dollar benefit of YLLs averted exceeds the cost of resources utilized in delivering the scale-up. A BCR substantially greater than one would suggest that scale-up is a socially worthwhile investment in these terms. Monetizing YLL involves use of a concept known as the ''value of a statistical life year'' (VOSLY)[27] to quantify, in terms of a dollar equivalent, the population welfare gain associated with saving an additional year of life expectancy (or equivalently averting a single YLL).[23] The VOSLY is an aggregated estimate of how much personal consumption citizens would be willing to forego (as expressed through a reduction in their income) to increase life expectancy by one year. This trade-off is normally estimated using survey-based methods or through statistical modelling of labor market data that can identify how much income those in employment are prepared to trade for improved occupational safety, as revealed through market wages.[28–30] Although there are a number of alternate methods for monetizing the benefit of mortality risk reduction in health policy analysis, we chose the VOSLY approach because it is preference-based; accords most closely with the principles underpinning BCA.[23,31] and has been recently applied to value the economic impacts of surgical disease.[4]

Modelling YLL Averted

The total YLL averted through scale-up of the Checklist is estimated by combining relevant clinical, epidemiological and surgical volume data into the following model:

$$\mathrm{YLL} = [(\mathrm{P}^1 \times \mathrm{L}^\mathrm{E}) \times \mathrm{q}] + [(\mathrm{P}^0 \times \mathrm{L}^\mathrm{E}) \times (\mathrm{N}\text{-}\mathrm{q})]$$

Where P^1 and P^0 is the average risk (probability) of postoperative death per procedure with and without the use of the Checklist, respectively, L^E is average age-and sex-weighted remaining life expectancy for patients undergoing surgery discounted at an appropriate rate, N is the total number of surgical procedures expected over a year and q is the total number of procedures exposed to Checklist use. For this study, we estimate YLL over a relatively short three-year time horizon: although investment in activities to support scale-up could benefit patient populations for longer periods, a more extended time horizon introduces more uncertainty (for example in expected surgical volumes in more distant periods and in expected sustainability of Checklist use in the long-run).

The total YLL averted through the Checklist scale-up in each of the three countries included in the study is then calculated as the difference between total YLL expected when q is at a level observed post scale-up and the total YLL expected had pre-scale up levels of Checklist use continued.

Model Parameters

Table 1 details the ''base case'' assumptions made regarding the value of all model parameters. The ''baseline'' probability of post-operative death (P^0) is assumed to take a value of 0.021. This is based on published 30-day surgical mortality data from the African Surgical Outcomes Study, which prospectively analyzed surgical outcomes of 11,422 patients in 25 African countries.[14] A recent meta-analysis of 42 unique studies conducted in LMICs reported a mean Checklist effect equivalent to 23% reduction in the baseline postoperative mortality risk (based on an estimated relative mortality risk of 0.77).[16] We used this value of 23% because it is based exclusively on LMIC data (whereas other meta-analyses of the Checklist report greater mortality reductions ranging from 23% to 43%,[11,12] but include high-income country data). Using this evidence, we assume that the probability of death with use of the Checklist (P^1) would be 0.016 (ie, a 23% reduction in P^0).

TABLE 1. Base Case Assumptions for Model Parameters

	Benin	Cameroon	Madagascar
Checklist effectiveness: reduction in postoperative probability of death as a % of mortality risk without use of checklist	23%	23%	23%
Average life expectancy for postoperative survivor sex and age weighted (discounted life expectancy)	47 yr (24 yr)	41 yr (22 yr)	45 yr (23 yr)
Age group weightings:			
0–14 yr	0.46	0.42	0.39
15–24 yr	0.20	0.20	0.20
25–54 yr	0.29	0.31	0.33
55–64 yr	0.03	0.04	0.05
65+ yr	0.02	0.03	0.03
Sex weighting (female)	0.66	0.66	0.66
Annual volume of procedures for facilities included in scale-up	41,002	20,916	16,998
% procedures where checklist was used: prescale up	31%	20%	8%
% procedures where checklist was used: postscale up	86%	56%	78%
Value of a statistical life*	$72,489	$148,782	$39,589
Value of a statistical life year*	$1888	$4057	$1079
Discount rate	3%	3%	3%
Number of hospitals assessed	36	26	21
Population^	12,864,634	27,744,989	26,955,737
Country area (square kilometers)†	112, 622	475,440	587,041

*Purchasing power parity adjusted 2016 values.
†Data source: www.cia.gov.

Average life expectancy (L^E) for patients who survive surgery is assumed to be the same as that for the wider population of comparable age. In a high-income context this could overestimate YLL, given that many surgical patients may already have survival prognosis compromised by existing health conditions. However, in a LMIC context we take this to be a reasonable assumption given that in the African Surgical Outcomes Study most surgical patients were previously healthy and younger than those reported in high-income country studies. Country-specific life expectancy was estimated using published life tables.[32] Estimates are sex-weighted to reflect the proportion of procedures carried out on male and female patients in LMICs. Sex-weighted life expectancy is subsequently estimated for the mid-point of the following age grouping: 0 to 14; 15 to 24; 25 to 54; 55 to 64; and 65+ years (using life expectancy at age 70 years). A single age- and sex-weighted life expectancy estimate is used, age weighted according to the percentage of the population within each of the adopted age groupings in each country studied. This assumes that surgical patient age structure reflects that of the wider population, which is a reasonable assumption based on epidemiological data of surgical need in children under 15 years of age.[33]

Expected annual volume of surgical procedures (N) was determined using hospital records (year 2014/15 Madagascar; 2015/16 Benin; 2016/2017 Cameroon) on the volume of surgical procedures undertaken across 83 separate facilities that participated in Checklist scale-up. The annualized surgical volume data for Benin, Cameroon and Madagascar were collected by Mercy Ships and used internally within Ministries of Health for Checklist implementation and NSOAP planning and made available to us. The quantity (q) of surgical procedures where the Checklist was used both pre and postscale-up was derived from published studies.[17–19]

Value of a Statistical Life Year

There are no estimates of the VOSLY directly applicable to Benin, Cameroon or Madagascar; hence the dollar value for each YLL averted through Checklist use is indirectly inferred. The inference process uses a methodology recommended in recently published guidelines on estimating the value of a statistical life (VOSL) and the VOSLY for use in the benefit-cost appraisal in a global public health context.[23] This involves recalibrating an existing accepted estimate of the VOSL used in project and policy appraisal from a ''base'' country (for this study, we use a VOSL used by United States government regulatory bodies) to a value more applicable to the country in question, accounting for cross-country per capita income differentials. For a country ''X'' the following formula is applied:

$$\mathrm{VOSL}_X = [\mathrm{VOSL}_{base}/\mathrm{GNI}_{base} \text{ per capita}] * [\mathrm{GNI}_X \text{ per capita}/\mathrm{GNI}_{base} \text{ per capita}]^{\beta-1}$$

GNI refers to gross national income (per capita) and ''β'' is the income elasticity with respect to the VOSL – and empirically estimated measure of the responsiveness of VOSL estimates to differences in national income levels ($\beta = 1.5$ is recommended for countries with national income levels applicable to those included in this study).[23] The VOSLY is then estimated by dividing the recalibrated VOSL by half the remaining life-expectancy at birth for the country in question.[23]

Cost of Scale-up

Total costs of resources expended on Checklist scale-up activities in each country were estimated from Mercy Ships accounts data. Although some of the Mercy Ships staff were volunteers, we estimated their salary costs from national wage scales for United Kingdom doctors and nurses. Salary costs for project coordinators, medical and nursing training facilitators and local medical staff who contributed to scale-up activities were included in the total Checklist implementation costs. Travel and accommodation costs were also included in addition to the cost of supplies (eg, office equipment and internet connections) and the purchase of new pulse oximetry equipment required to support Checklist use. The analysis excludes the opportunity cost of the clinical time sacrificed by surgical staff in attending education and training sessions, though in all cases there was no requirement to delay or cancel surgical procedures on account of attending education and training events. All implementation costs in the analysis are treated as one-off fixed investment costs incurred within a 12-month implementation period. For simplicity, we assume that project population benefits are generated over the three years after the initial implementation year.

Study Perspective, Discounting, and Currency

The analysis is conducted from the project implementer perspective (in this case the nongovernmental organization): we excluded an assessment of wider beneficial impacts of increased surgical safety, including resource savings to the health system (eg, reductions in bed days, usage of medical consumables) and macroeconomic benefits relating to averting lost productive output due to years of healthy life lost. Life-expectancy values for estimation of the YLL from postoperative mortality and the total YLL averted through Checklist scale-up (and its dollar equivalent) over the 3-year study time horizon are both discounted at a rate of 3%, as recommended by the WHO.[21] For comparability, all costs and the dollar value of YLL averted are expressed in international USD using World Bank purchasing power parity conversion factors applied to local currency units.[34] All dollar values are reported in 2016 prices.

Sensitivity Analysis

Despite supporting evidence and data, all base-case assumptions concerning model parameters are subject to uncertainty regarding their true value. Decision-makers therefore need to be aware of whether plausible deviations from these base assumptions could change the central conclusions reached by an economic evaluation. To examine this, we apply a threshold analysis (a form of 1-way sensitivity analysis) to the base-case modelling assumptions. For the BCA, we determine the value that each parameter would need to take for Checklist implementation to ‘‘break-even’’ (a BCR = 1). For the CEA, we identify the parameter values at which each country-specific ICER equates to the threshold used by WHO to determine ‘‘cost-effective’’ versus ‘‘very cost-effective’’ health program (ICE-R = GNI per capita) and the threshold above which program are no longer viewed as cost-effective (ICE-R = three times GNI per capita).[25] The threshold values are identified for: effect of Checklist on postoperative mortality (% reduction in probability of death); average life-expectancy of surgical survivors; % point change in the number of procedures where Checklist is used; total cost of scale-up; and the VOSLY. We also vary the discount rate from the base case rate of 3% and adopt WHO recommendations by estimating BCR and ICER assuming a rate of 0% and 6%.[21]

All analyses were conducted using Microsoft Excel.

Role of the Funding Source

The funding sources declared by the authors had no involvement in this study.

TABLE 2. Results of the Economic Evaluation of the WHO Checklist Scale-up Programs in Benin, Cameroon, and Madagascar

	Benin		Cameroon		Madagascar	
Annual YLL averted	2,583		797		1,335	
Present value of YLL averted over 3 yr	$13.6 million		$9.1 million		$4.1 million	
Total cost of scale-up	$223,530		$311,357		$447,081	
ICER (cost per additional YLL averted over 3 yr)	$31		$138		$118	
BCR	62		29		9	
Sensitivity analysis						
Discount rate	0%	6%	0%	6%	0%	6%
ICER	$15	$51	$70	$224	$58	$151
BCR	130	37	58	18	19	7
BCA threshold values (BCR — 1): Checklist effectiveness: reduction in post-operative probability of death as a % of mortality risk without use of checklist	0.37%		0.78%		2.52%	
Discounted average life expectancy for survivors	0.38 yr		0.75 yr		2.55 yr	
% point change in volume of procedures where checklist is used	<1%		1%		8%	
Total cost of scale-up	$13.6 million		$9.1 million		$4.1 million	
Value of a statistical life year	$31		$138		$118	
CEA Threshold Values:	**ICER = GNI Per Capita**	**ICER = 3 Times GNI Per Capita**	**ICER = GNI Per Capita**	**ICER = 3 Times GNI Per Capita**	**ICER = GNI Per Capita**	**ICER = 3 Times GNI Per Capita**
Checklist effectiveness: reduction in postoperative probability of death as a % of mortality risk without use of checklist	0.33%	0.11%	0.91%	0.30%	1.60%	0.53%
Discounted average life expectancy for survivors	0.34 yr	0.11 yr	0.88 yr	0.29 yr	1.62 yr	0.54 yr
% point change in volume of procedures where checklist is used	<1%	<1%	1%	<1%	5%	2%
Total cost of scale-up	$15.8 million	$47.3 million	$7.9 million	$23.6 million	$6.4 million	$19.3 million

YLL, years of life lost; ICER, incremental cost-effectiveness ratio; BCR, benefit-cost ratio; BCA, benefit-cost analysis; CEA, cost-effectiveness analysis; GNI, gross national income.

RESULTS

For Checklist scale-up in Benin, Cameroon, and Madagascar ICERs and BCRs (modelled over 3 years) were: $31, $138, and $118 per YLL averted; and 62, 29, and 9, respectively (see Table 2).

Table 2 also shows the values used to calculate the ICERs and BCRs: the annual YLL averted; the present monetized dollar value of YLL averted discounted over 3 years; the total implementation costs of Checklist scale-up; and the sensitivity analysis. The BCA sensitivity analysis shows that for Checklist implementation to ''break-even'' the Checklist only needs to reduce mortality by between 0.4 and 2.5% instead of the current estimates of 23%; and that efforts to expand Checklist scale-up only need increase Checklist use by between 1% and 8%, instead of the current evidence of increases of more than 50% (shown in Table 1). The CEA sensitivity analysis shows similar thresholds, that is, for the Checklist to still be considered ''very cost-effective,'' scale up only needs result in an increased Checklist usage of between 1% to 5%, and associated reductions in mortality of less than 1.6%.

DISCUSSION

In this study, we report incremental cost-effectiveness and benefit-cost ratios of nationwide scale-up of Checklist use in 3 different sub-Saharan countries. The ICERs are $31, $138, and $118 per YLL averted, and the BCRs are 62, 29, and 9 for Benin, Cameroon, and Madagascar, respectively. The sensitivity analysis we carried out further supported these findings: for our main conclusions to change, clinical and economic parameter values would require large, arguably implausible, deviations from the evidence-informed values we applied.

Policy Interpretation

BCA is designed to identify whether government programs improve social wellbeing (benefit-cost ratio >1) and can facilitate comparability of the relative net-worth of projects to society across different sectors (eg, a health versus transportation program). The BCRs were all considerably above one: for every $1 USD spent, the potential return on investment ranged from $9 to $62. This means that if LMICs governments invested in nationwide Checklist scale up they would achieve a good social return on investment which would help further UHC compared with other nonhealth interventions aspiring to attain worthwhile but competing Sustainable Development Goals (Table 3). Currently 5 sub-Saharan African countries have published NSOAPs and all target increased Checklist use.[35] Our study supports these policy decisions.

CEA is concerned with how best to allocate health system budgets. According to WHO criteria,[25] any intervention that costs a health system less than the GNI per capita per DALY averted is considered ''very cost-effective.''[26] Since the GNI per capita for Benin, Cameroon, and Madagascar range from $1700 to $3490, respectively,[36] ICERs of $31 to 118 per YLL averted therefore imply that Checklist scale-up is ''very *cost-effective''* when judged against this benchmark. Our ICERs for Checklist scale-up compare favorably with those of other health interventions (Table 4).

Variations in ICER and BCR between countries were small (eg, compared to recent estimations of ICER for cataract surgery, which varied 100-fold across continents[7]). This is reassuring and probably due to all three countries being sub-Saharan LMICs. Cross-country variations in country size, transportation infrastructure, and number of pulse oximeters required are factors that explain differential costs. For the BCA, the country specific VOSLY, which partly varies with income per capita, means that life years saved are also valued differently between localities. The volume of surgical procedures and the magnitude of scale-up in Checklist use is an important driver of social returns and cost-effectiveness across all three countries. The assumed 23% reduction in postoperative mortality risk on an assumed baseline risk of 0.021 does not translate into large expected gains in life expectancy per patient. However, this impact aggregated over large volumes of surgical procedures translates into a considerable magnitude of YLL avoidance.

Our study has limitations. Our ''base case'' estimates use evidence on the Checklist implementation which came mainly from self-reports (albeit triangulated with direct observations)[17–19]; and we do not know how much Checklist use would have increased without any implementation activities. Our sensitivity analysis was ''deterministic'' rather than ''probabilistic''; as such our analysis

TABLE 3. Benefit Cost Ratios of Health and Nonhealth Interventions

Health Interventions	Benefit-Cost Ratio
WHO surgical safety checklist[*]	*9–62*
Caesarean section, globally[†]	4
Essential surgical procedures, globally[‡]	10
Cleft lip and palate repair, India[†]	14
Nonhealth Interventions	**Benefit-Cost Ratio**
Hill forest development project, Nepal[§]	1.2
Irrigation systems improvement project, Philippines[§]	1.5
Livestock development project, Uruguay[§]	1.6
Livestock and agricultural development project, Paraguay[§]	1.6
Cotton processing and marketing project, Kenya[§]	1.8
Investment to retrofit schools in India to better withstand earthquakes, India[†]	0.04–5.6
Reducing the prevalence of stunting by a package of interventions targeting malnutrition, India[†]	44–138
Formal scholarship schooling program, Columbia[§]	3–26
Adult basic education and literacy program, Columbia[§]	8–1,764
School-based reproductive health program to prevent HIV/AIDS, Honduras[§]	0.1–5
Iron supplementation administered to secondary school children (low-income country)[§]	26–45
Tobacco tax (middle-income country)[§]	7–39

*This study 2020.
†Alkire 201 5.[38]
‡Jamison 2013.[3]
§Knowles 2003.[39]

TABLE 4. Incremental Cost-Effectiveness Ratios of Surgical Interventions and Compared With Other Public Health Interventions

Surgical Intervention	Cost Per DALY Averted ($USD)
WHO surgical safety checklist	*$31–$118 per YLL averted*[*]
Male circumcision	$7–$106[†]
Cleft lip and palate surgery	$47[‡] (or $15–$96[†])
General surgery	$82[‡]
Hydrocephalus surgery	$108[‡]
Ophthalmic Surgery	$136 [‡]
Orthopedic surgery	$381[‡]
Caesarean Section	$315[‡]
Other Health Interventions	**Cost Per DALY Averted ($USD)**
Vitamin A supplementation	$6–$12[‡]
BCG vaccination	$51–$220[‡]
Anti-retroviral therapy for HIV	$453–$648[‡]
Medical therapy for ischemic heart disease	$500–$706[‡]
Breast-feeding promotion	$930[†]
Oral rehydration solution therapy	$1062[†]

*This study 2020: costs converted to International Dollars using World Bank purchasing power parity conversion factors at 2016 prices.

†Grimes 2014[8]: costs converted to USD using Gross Domestic Product (GDP) deflators and then purchasing power parities

‡Chao 2014[7]: costs converted to USD using Consumer Price Index Inflation Calculator; or if original study reported International Dollars then used Atlas method with GDP per capita.

does not account for all aspects of uncertainty simultaneously – including, for example, sampling uncertainty relating to the key parameters of relevance. We assumed that the life expectancy of those undergoing surgery was the same as the life expectancy for the population as a whole. However, if an individual who needs surgery has a shorter life expectancy (for reasons related or unrelated to their surgical condition), then our base-case results will have over-estimated the cost-effectiveness and economic benefits of Checklist use. On the other hand, by using YLL averted rather than DALYs averted; and not taking account of the macro-economic impacts relating to lost productive output averted from years of healthy life lost, our results offer a conservative analysis of the economic case for Checklist scale-up. VOSL estimates do not exist for the countries in this study and are therefore indirectly estimated in the absence of country-specific valuation data. Our results are context-specific and not immediately transferable to different countries. Finally, we did not aim to undertake a detailed probabilistic economic evaluation of the type typically applied in Health Technology Appraisal. Instead the analysis we present brings together the relevant evidence to evaluate whether there is a prima-facie economic case for Checklist scale-up nationally.

Our study also has strengths. This is the first economic evaluation of the WHO Checklist in LMICs, which is one of the best-evidenced surgical improvement interventions; was intended by WHO to be implemented at scale in all LMICs[37]; butis currently only used in approximately a third to half of surgical patients.[13–15] We have estimated both ICERs (which allow comparison with other health interventions) and BCRs (which allow more intuitive review by policy-makers managing country-level budgets). In presenting our results for each country individually, the study allows transferability of our results to other LMICs of similar geographical size, surgical volume, and resource constraints.

In summary, nationwide WHO Checklist scale-up was found to be very cost-effective and to produce a good social return on investment in Benin, Cameroon, and Madagascar. Ourresults support the economic argument for financing national Checklist implementation through NSOAPs as part of UHC.

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