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The Economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone

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The Economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone

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Abstract

Objectives: The Lancet Commission on Global Surgery estimated that low and middle-income countries (LMICs) will lose an estimated cumulative loss of US\$12.3 trillion from gross domestic product (GDP) due to the unmet burden of surgical disease. However, no country specific data currently exists. We aimed to estimate the costs to the Sierra Leone economy from death and disability which may have been averted by surgical care.

Design: We used estimates of total, met and unmet need from a number of sources including a cluster randomised, cross-sectional, countrywide survey and a retrospective, nationwide study on surgery in Sierra Leone and a population survey of surgical disease in Sierra Leone. We calculated estimated lost disability-adjusted life years (DALYs) from morbidity and mortality for the estimated unmet burden and modelled the likely economic impact using three different methods – Gross National Income (GNI) per capita, lifetimes earnings foregone, and value of a statistical life.

Results: In 2012, estimated, discounted lifetime losses to the Sierra Leone economy from the unmet burden of surgical disease was between \$1.1-3.8 billion, depending on the economic method used. These lifetime losses equate to between 23%-100% of the annual GDP for Sierra Leone. 80% of economic losses were due to mortality. The incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80% were calculated to be between US\$360 million – US\$2.9 billion.

Conclusion: There is a large economic loss from the unmet need for surgical care in Sierra Leone. There is an immediate need for massive investment to counteract on-going economic losses.

Article Summary**Strengths and limitations of this study**

- The Lancet Commission on Global Surgery estimated cumulative losses from unmet surgical need of US\$12.3 trillion globally. This is the first country-specific study to estimate macroeconomic losses.
- Estimates of unmet need in this study are based on previous studies. It is not possible to be certain the exact unmet surgical need is.
- Likewise, true death and disability averted is impossible to be accurately determined and is based on estimates.
- All modelling strategies have their limitations, especially in resource-poor settings. Therefore we used three different approaches for comparison.

Introduction

Although once described as the “neglected stepchild of global health”,¹ surgery is increasingly being recognised as an indivisible, indispensable part of health care.² Currently, surgical disease accounts for an estimated 33% of the global burden of disease³, with an estimated 5 billion people have no access to safe, affordable surgical care and anaesthesia when needed⁴ and an estimated 143 million additional procedures needed in low and middle-income countries (LMICs) to save lives and to prevent disability.⁵ Surgical access is weakest in low-income countries.⁶ Although traditionally thought of as an expensive intervention, cost-effectiveness analyses have shown that surgery – both individual procedures and surgical platforms - are highly cost-effective compared with other global health interventions⁷.

A number of studies have shown the profound economic impact on individuals and households resulting from untreated surgical conditions, with resulting death and disability.^{8, 9} However, treatment of such conditions can improve the quality of life, household income as well as social status.¹⁰ Reducing deaths and disability from road traffic accidents alone in LMICs to the level of high income countries would result in a potential economic saving of US\$758-786 billion per year.¹¹ If there is no accelerated urgent scale up of surgical services, LMICs are estimated to lose a cumulative US\$12.3 trillion to their economies over the next 15 years.⁵

To date, there have been no country specific estimates of the economic costs resulting from loss of productivity due to death and disability from surgically treatable disease. Sierra Leone has been estimated to have a high burden of surgical disease, with a household survey suggesting that 25% of deaths in the previous year may have been averted by timely surgical intervention, and 25% of respondents claiming to have a surgical condition requiring attention.¹² Results from a national survey reported that there were 24,152 operations in Sierra Leone in 2012 across all hospitals (government and private) amounting to a national average of 400 operations per 100,000. This amounts to approximately 8% of surgical disease treated and 92% untreated. Our aim was to estimate the likely impact on the Sierra Leonean GDP resulting from this untreated surgical disease.

Methods

Disability Adjusted Life Years

The disability adjusted life year (DALY) is a composite measure of health quantity and quality which seeks to capture the negative consequences of premature mortality alongside burden from morbidity for the duration of an illness:

$$DALYs = YLD + YLL \quad (1)$$

$$YLD = I \times D \times DW \quad (2)$$

$$YLL = N \times LD \quad (3)$$

Where YLD is the number of years lost due to disability, I the incidence of a condition, D the duration of illness, DW the disability weight, YLL the years of life lost, N the number of deaths from a condition, and LD the life expectancy at age of death. DALYs are sometimes weighted differently according to the age at which a person dies, in theory to reflect societal values around death at younger age. This is a controversial topic in the calculation of DALYs and, as in WHO GBD studies since 2001, we do not apply age weighting in this analysis. We used local life expectancies from the World Health Organisations Life Table for Sierra Leone in 2012¹³ and disability weights published by the Global Burden of Disease (GBD) Study.¹⁴

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4 The need for surgery in Sierra Leone was calculated from two cluster randomised, cross-sectional,
5 countrywide surveys.^{12, 15} Details of all operations performed in Sierra Leone in 2012 from every
6 surgical provider was obtained from a nationwide, retrospective study.¹⁵ Data were excluded if there
7 was no recorded age for the patient, or no recorded operation. The remaining records were then
8 analysed. For each operation, we used a weighting system used by previous authors^{16, 17} to
9 determine the likely threat to life without treatment, the likelihood of permanent disability, and the
10 likely efficacy of treatment (Table I). Weights for each operation were estimated using a Delphi
11 method of local doctors and experts in each field. Operations were weighted differently depending
12 on whether they were “emergency” or “planned” operations. Those where it was unclear whether it
13 was performed as a planned or an emergency operation, were weighted as for a “planned”
14 operation. The occurrence of DALY-causing mortality was calculated by:

$$N = \text{Life Expectancy} \times \text{Likely threat to life} \times \text{Efficacy of treatment}$$

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19 For those conditions that predominantly cause disability, we used the formula

$$I = \text{Life expectancy} \times \text{risk of permanent disability} \times \text{disability weight} \times \text{efficacy of treatment}$$

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24 Operations were deemed to either avert death or disability as in table II.

25 26 27 **Calculating economic losses**

28 A number of methods are available to calculate economic losses due to preventable health
29 conditions, and we opt to take three approaches which are simple and transparent in nature.

30
31 Acknowledging the breadth of literature in this area, we use three different approaches to estimate
32 productivity losses from unmet surgery need: two applying the human capital approach (HCA), firstly
33 using inputs of GDP/capita, and secondly lifetime earnings forgone, alongside a method
34 incorporating the value of a statistical life.

35
36 Both HCA approaches use national accounts or workforce participation and earnings data, and do
37 not require extensive assumptions around the structure of the Sierra Leonean economy. These
38 methods may therefore underestimate economic losses because they do not capture dynamic
39 effects of reductions in morbidity or mortality, for example the economic productivity from
40 additional children of persons whose death is delayed by surgery. The methods are consistent with
41 the growing consensus in health economic evaluation that the societal perspective should be
42 considered where possible to give a more accurate reflection of true economic losses to society,
43 outside of direct health expenditure.¹⁸

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46 The value of a statistical life (VSL) is the amount of money a person or society is willing to spend to
47 save one life, and is commonly used by public bodies to value lives saved in cost-benefit analyses of
48 health, transport or environmental projects.¹⁹ Data often comes from the labour market, where
49 individuals sometimes make decisions that involve a trade-off between financial rewards and an
50 increased risk of premature mortality. Economists use this revealed preference for risk to calculate
51 their VSL, reflecting the amount individuals are willing to pay to avert the risk of dying. For example,
52 if a welder on an oil rig was willing to accept a pay cut of £1,000 to work on land where the risk of
53 death was 0.001 lower, their VSL would be £1 million (£1,000/0.001). VSL estimates are often larger
54 than production-based measures of welfare losses (including the HCA), but fit better into welfare
55 economic frameworks because they allow the worth of individuals to be greater than their wage
56 rate.
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We present economic losses both as an absolute number for income loss discounted to \$USD 2014 and as a percentage of gross domestic product (GDP), however we note caution in interpreting the latter. Household earnings (and subsequent consumption) are elements of GDP calculations, alongside aggregate government expenditure and business investment, amongst others. As elsewhere in the literature,²⁰ we use the comparison between projected losses and actual GDP as a useful relative frame to understand the large numbers produced by this model. However, we emphasise that these are not directly causal and, in fact, may understate the direct effect of unmet surgery need on GDP. Finally, we compare figures to the 2014 GDP of Sierra Leone. Because of the severe impact of Ebola virus disease (EVD), Sierra Leone's economy contracted by 20% between 2014 and 2015.

Modelling approach

First, we generate a counterfactual scenario where all annual mortality and disability is avoided by assuming current met need is 8%, as estimated by Bolkan et al¹⁵ although this is likely to be a conservative estimate. Then we present different scenarios of met need according to published studies and benchmarks, aggregating reductions in mortality and morbidity separately.

The literature has not reached consensus on how to estimate productivity losses due to morbidity.¹⁹ We take a pragmatic approach and obtain condition-specific data from the literature to estimate the proportion of persons with surgically treatable conditions who were unable to work following the development of a condition (Table II). Where no evidence of productivity effects are noted, we take a conservative approach and assume that untreated persons do not suffer productivity losses. Further information is provided in supplementary file I.

Estimation of Economic losses

We use three methods to estimate economic losses:

1) Gross National Income per capita

A common application of the HCA, recommended by the WHO Commission on Macroeconomics and Health, is to use Gross National Income per capita to estimate the potential economic gains from gaining an additional year of life.²¹ This approach has been applied elsewhere to estimate economic gains and losses of health interventions. Although the GNI/capita approach may undervalue benefits from averting a DALY as it does not account for externalities on the wider labour market or care required from family members, the method is transparent and broadly accepted in the literature.¹⁹ Thus, GNI/capita approximates the economic value that the average individual adds to a society per year and we simply multiply GNI/capita by the number of DALYs averted in each scenario of met surgical need.

2) Lifetime earnings forgone

The GNI/capita approach does not necessarily equate to the majority of individuals' economic productivity, particularly in unequal economies such as Sierra Leone, where few very productive individuals may bias mean earning estimates. Therefore we calculate the present value of lifetime earnings (PVLE) forgone for each age category, slightly adapting the model presented in Menzin et al.²²:

$$PVLE_{paid(i,j,k)} = \sum_{i=s_j}^{n_j} \frac{(l_{i,j,k} * w_{i,j,k})}{(1+r)^{i-s_j}} \quad (4)$$

Where the estimated losses for a cohort of persons with age i , gender j , working in employment sector k , and with life expectancy s_j , are a weighted average of their economic activity, l , and wage rate w . We split each gender into five age groups, driven by the availability of data on avertable mortality and morbidity, and use the midpoint of each strata to estimate years of productive life remaining.

We use data from the nationally representative 2011 Sierra Leone integrated household survey (SLIHS)²³ to obtain estimates of labour force participation by gender. We estimate the proportion of the population not in the labour force, the proportion employed in agriculture, and the proportion in other waged industry. For both employed groups, we use SLIHS data to calculate the number of hours worked per year and apply earnings and salary data to estimate total annual earnings.

3) Value of a statistical life

A number of methods exist to calculate the VSL in Sierra Leone, which are briefly summarised in supplementary table I. For our main analysis we use \$90,700 as calculated for sub-Saharan Africa by Robinson and Hammit.²⁴ We follow Alkire et al²⁵ and convert this VSL into its annualised equivalent, the value of a statistical life-year (VSLY), for use with DALYs. Here we assume that the VSL is analogous to an annuity, giving a constant stream of income of \$31,415 per year (5% discount rate). Consistent with DALY calculations we do not apply age weighting to this value so assume it remains constant throughout a lifetime. The use of Sierra Leonean data negates the re-scaling of VSL from the USA, as elsewhere.^{24, 26}

Discount Rate: The choice of discount rate can have a large impact on the results of an economic analysis, particularly when benefits or costs occur a long time after initial expenditure.²⁷ We use a discount rate of 5% on costs and benefits. We explore the effect of higher discount rates in a sensitivity analysis.

Uncertainty and sensitivity analyses: We use a deterministic sensitivity analysis to explore methodological uncertainty stemming from the choice of discount rate, exploring a zero discount rate, 3% as per guidelines, and 8.7% to mirror the local inflation rate. We carry out a multivariate probabilistic sensitivity analysis with 1000 Monte Carlo simulations of a number of variables simultaneously to assess the impact of parameter uncertainty on model predictions, and present included parameters and distributional assumptions in supplementary table II

Results

Met need in 2012

Out of the 24,152 operations recorded as being performed in Sierra Leone in 2012, 46% were excluded – 5,672 because of a lack of detail about the operation and 5,415 because there was no age recorded. 6,141 of the remaining operations were death averting, and 6,924 were disability averting (Table III). Accounting for the probability of success in death-averting operations, 2,219 deaths were averted through surgical intervention in 2012 (Table IV).

Health losses due to unmet need

Assuming that the 24,152 operations recorded in 2012 represent 7.9% of met surgical need in Sierra Leone,¹⁵ we estimate that unmet surgical need in 2012 resulted in 766,606 DALYs forgone: 606,981

DALYs lost due to mortality and 159,625 due to morbidity. If surgical provision could be increased to 80% in line with the recommendations of The Lancet Commission on Global Surgery, an additional 599,953 DALYs would be averted compared to 2012 provision. Reaching the goal of 50% provision would avert an additional 349,972 DALYs, whilst the pragmatic target of 20% provision would result in 99,992 additional DALYs averted.

Economic losses

Figure I presents estimated discounted economic losses from unmet surgery need. As anticipated, using different approaches to estimate losses, resulted in vastly different figures. The value of a statistical life approach gave the highest figure: current economic losses due to unmet surgery need were estimated to be \$3.8 billion (all monetary figures presented as 2012 USD), equivalent to 107% of Sierra Leone's GDP in 2012. The GNI/Capita approach put forward by the WHO Macroeconomic Commission gave the next highest figure of \$1.4 billion (42% of 2012 GDP), whilst the lifetime earnings forgone method gave an estimate of \$1.1 billion (31% of 2012 GDP). Economic losses due to mortality contributed to around 80% of total economic loss from unmet need across all measures. Finally, table V presents the incremental losses that would be averted if surgical provision were to be scaled up to each of the three target scenarios.

Sensitivity analyses

Figure II displays results from a one-way sensitivity analysis, analysing the change in estimates of unmet need as model parameters are varied in isolation. Estimates are particularly sensitive to assumptions of current unmet need and whether the DALY estimates consider morbidity in addition to life years lost. Assumptions of earnings do not make a substantive difference to estimates using the lifetime earnings forgone method.

Figure III displays the results of a probabilistic sensitivity analysis alongside base case estimates, whilst error bars illustrate the 25th and 75th quartiles of Monte Carlo model runs. When accounting for parameter uncertainty in the PSA, the model still predicts substantial economic losses due to unmet surgical need. Of all probabilistic simulations, 38% of estimates were greater than the deterministic estimate. The variability of VSL simulation estimates is between 61% and 73% greater than that of human capital approaches.

Discussion

In 2013, the Lancet Commission on Investing in Health argued that investing in healthcare in LMICs produced profound returns on investment of between \$9-20 for every \$ invested.²⁸ The question thus arose as to whether investment in the provision of surgical services to avert death and disability would give a similar financial return on investment. This question was addressed by the Lancet Commission on Global Surgery which presented data on both the economic impact of untreated disease and the financial commitment required to scale up surgical services. Alkire et al calculated projected economic losses in LMICs from a variety of surgical conditions using the Value of Lost Output approach of up to 2.5% of annual GDP and 17% of 2010 GDP if a Value of Lost Welfare approach was used.²⁹ Verguet et al³⁰ modelled the possible scale up of surgical services in low and middle income countries for the Lancet Commission on Global Surgery target of 5000 operations per 100,000 population per year and calculated that costs of US\$300-420 billion would need to be met to achieve scale up over the years 2012-2030, representing 4-8% of total annual health expenditure. This large investment in scaling up surgical services across 88 LMICs was positive when compared with the \$12.3 Trillion loss to economic growth in these countries if surgical service development was neglected. The Lancet Commission on Global Surgery data presented a similar picture presented to the Lancet Commission on Investing in Health – investing in surgical care was beneficial and produced significant economic returns on investment.

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4 The few studies that have been published on the macroeconomic impact of surgical disease in low
5 and middle income countries, all show significant costs to national economies.^{11, 29} This study
6 demonstrates significant estimated costs to the economy of Sierra Leone from untreated surgical
7 disease. It is the first single country study and also represents a move away from modelled data to
8 the use of primary surgical data for an estimation of the economic impact of untreated disease. The
9 economic impact of untreated surgical disease in Sierra Leone is significant. In 2012, the estimated
10 cumulative loss to the Sierra Leone economy from the unmet burden of surgical disease was
11 between \$1.1-3.8 billion, depending on the economic method used. This equates to between 23%-
12 100% of the 2012 GDP for Sierra Leone. 80% of economic losses were due to mortality. The
13 incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80%
14 were calculated to be between US\$360 million – US\$2.9 billion, accepting that the Lancet
15 Commission target was for 80% access to the Bellwether procedures, not for all surgery.
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18 There are a number of limitations to this study. Firstly, we had to discard 46% of the surgical data
19 because it was incomplete. As a result, we worked with only 54% of the surgical data, which may
20 not have been fully representative and may have skewed the results. We assumed that this 54%
21 accounted for the 7.9% of met need, and calculated unmet need based on this, although of course, if
22 we had a full complement of data, the met need and hence the unmet need would have been
23 significantly greater.
24

25 Where data was absent, for example when a patient's age was recorded but not their gender, we
26 used complete data observations to weight how these were distributed across groups at the lowest
27 level of aggregation available, e.g. by age group. If observations were missing not at random (type-2
28 error), this could introduce bias into our estimates. We assumed operations not listed as either
29 "emergency" or "planned" were planned, so as to create a conservative estimate of the overall
30 economic impact. In practice, many of these may have been emergencies and would have made the
31 resulting economic losses even greater. We assumed that the same proportion of met and unmet
32 need was uniform across all operations. However, it may be that the proportion of met: unmet need
33 may be higher for certain operations because of the nature of the pathology and the urgency for
34 example, free healthcare for pregnant women might mean that the ratio of met: unmet need is
35 higher for caesarean sections than it is for emergency laparotomy. We also assumed that treating
36 a treatable condition would return the patient back to full economic productivity, although this may
37 not be the case.
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40 Economic losses estimated here do not consider the value of unpaid or domestic work because of
41 uncertainty in assumptions required, and because these do not form part of many estimates of GDP.
42 Omitting these factors makes our model more conservative and we are likely to underestimate total
43 economic losses, with a greater underestimation occurring in female groups. Averages (mean values)
44 are used to parameterise the model, and we therefore do not account for heterogeneity in
45 estimates except for between genders and the age at which surgery was required. Other literature
46 has shown a notable correlation between propensity for ill health and income, particularly in low-
47 and middle-income contexts such as this study, and this model does not account for this. The
48 lifetime earnings estimates in the human capital approach may overstate losses, and therefore
49 assume that premature mortality or morbidity causes a lifetime's impact to the economy. With more
50 data, we could have used a friction cost method to be more conservative, however, the lost earnings
51 estimates are the lowest produced in this study.
52
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54 Despite these limitations which are prevalent in much of the global surgical literature, we have
55 provided the first national study of economic losses based on as much data as is currently available
56 for Sierra Leone. This suggests massive economic losses, much of which may be avertable by the
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3 provision of timely, surgical care. What is now required is the development of a costed national
4 surgical plan as recently undertaken in Zambia. In the case of Sierra Leone, the necessary investment
5 might be more than the Lancet Commission on Global Surgery figure of 4-8% of total annual health
6 expenditure as there is likely to be a large initial capital outlay as well as a very significant necessary
7 investment in the surgical workforce. Only then will we be able to compare this required investment
8 with our economic loss figures to quantify the return on surgical system investment in terms of lives
9 saves and disability averted.
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Tables and Figures

Table I: Weightings

Weighting given	Risk of death or permanent disability	Treatment efficacy
0	Condition fatal or permanently disabling <5% of the time	<5% chance of permanent cure
0.3	Condition fatal or permanently disabling 5-50% of the time	5-50% chance of permanent cure
0.7	Condition fatal or permanently disabling 50-95% of the time	50-95% chance of permanent cure
1	Condition fatal or permanently disabling >95% of the time	>95% chance of permanent cure

Table II: Operations averting DALYs

Primarily death averting	Primarily disability averting	Assumptions of disability on earnings
Amputation	Cataract surgery	60% lifetime earnings lost
Appendectomy	Cleft lip repair	No impact (no literature found)
Caesarian section	Cystectomy	No impact (no literature found)
Cervical or vaginal laceration	Fracture	88% of earnings lost for one year
Chest tube	Hernia repair (planned/unknown)	18% (16-20%) lifetime earnings lost
Dilatation and curettage	Neonatal surgery (planned/unknown)	No impact (no literature found)
Hernia repair (emergency)	Obstetric fistula repair	97% lifetime earnings lost
Hysterectomy (all)	Urethral stricture dilation	No impact
Laparotomy (all)		
Malignancy		
Manual placenta removal		
Necrosectomy		
Neonatal surgery (emergency)		
Manual placenta removal		
Salpingectomy for ectopic pregnancy		
Ectopic pregnancy		
Tracheostomy		

Table III: DALYs averted by operation

Primarily death averting	Number of operations in 2012
Amputation	234
Appendectomy	1,114
Caesarian section	2,646
Cervical or vaginal laceration	24
Chest tube	35
Dilatation and curettage	508
Hernia repair (emergency)	166
Hysterectomy (all)	218
Laparotomy (all)	815
Malignancy	173
Manual placenta removal	65
Necrotectomy	1
Neonatal surgery (emergency)	13
Manual placenta removal	8
Salpingectomy for ectopic pregnancy	10
Ectopic pregnancy	103
Tracheostomy	8
Primarily disability averting	
Cataract surgery	2,242
Cleft lip repair	2
Cystectomy	16
Fracture	964
Hernia repair (planned/unknown)	3,435
Neonatal surgery (planned/unknown)	5
Obstetric fistula repair	201
Urethral stricture dilation	59
Total	13,065

Table IV: Summary of met surgical need in 2012

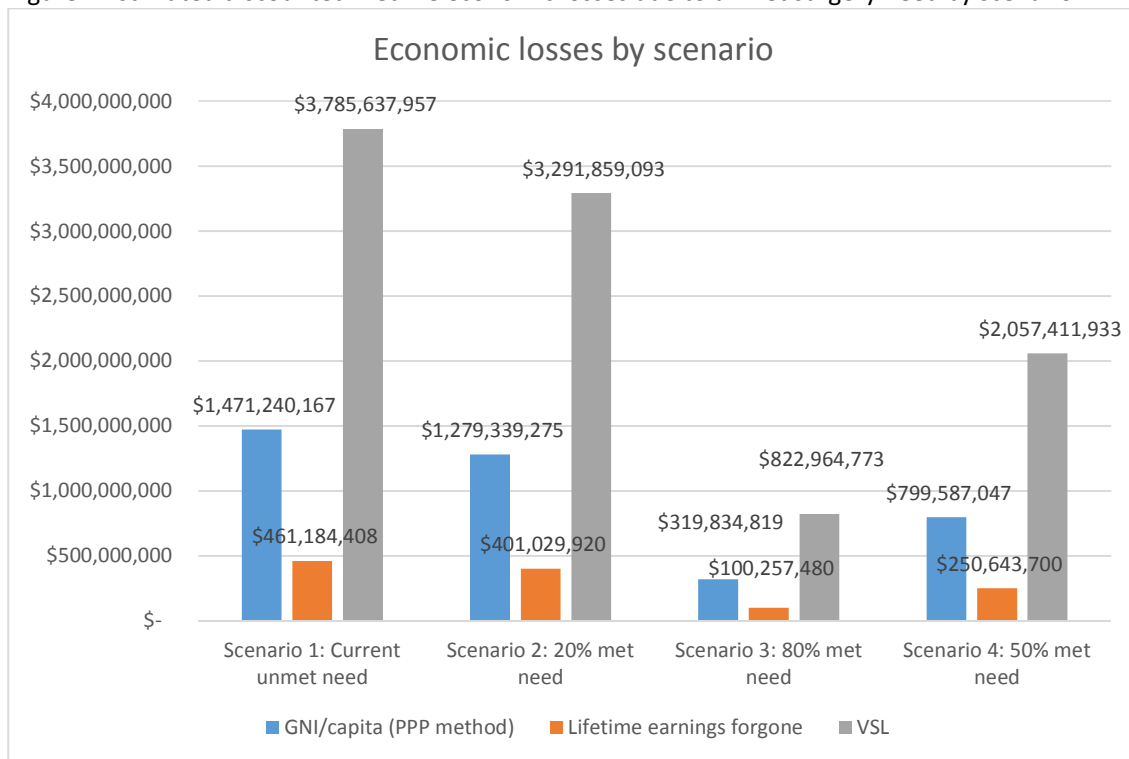
Age (years)	Deaths averted in 2012	Mortality DALYs averted due to surgery in 2012 (YLL)	Morbidity DALYs averted due to surgery in 2012 (YLD)
1-4	58	1,073	293
5-15	214	3,877	741
16-19	278	4,936	566
20-33	778	13,086	2,225
34+	332	5,173	3,626

Table V: Incremental losses averted by scale up of surgical provision compared to current met need

Incremental economic losses averted	Scenario 2: 20% met need	Scenario 3: 80% met need	Scenario 4: 50% met need
GNI/capita (ppp)	\$191,900,891	\$1,151,405,348	\$671,653,120
Earnings forgone (YLY only)	\$60,154,488	\$360,926,928	\$210,540,708
Value of a statistical life approach	\$493,778,864	\$2,962,673,184	\$1,728,226,024

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Figure I: Estimated discounted lifetime economic losses due to unmet surgery need by scenario



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Figure II: One way sensitivity analysis

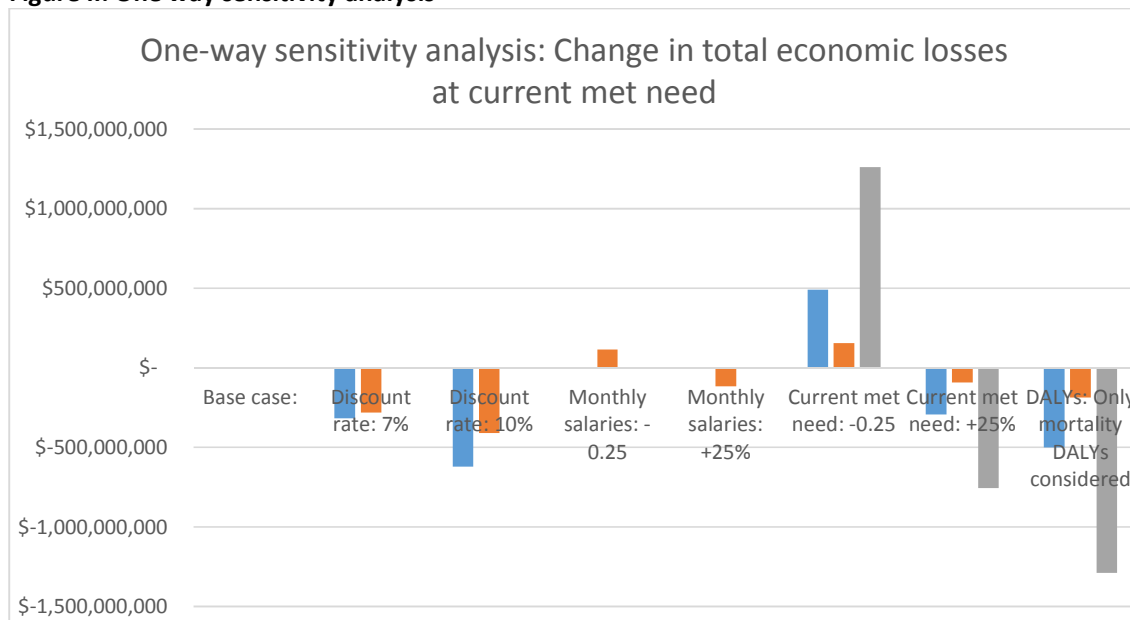
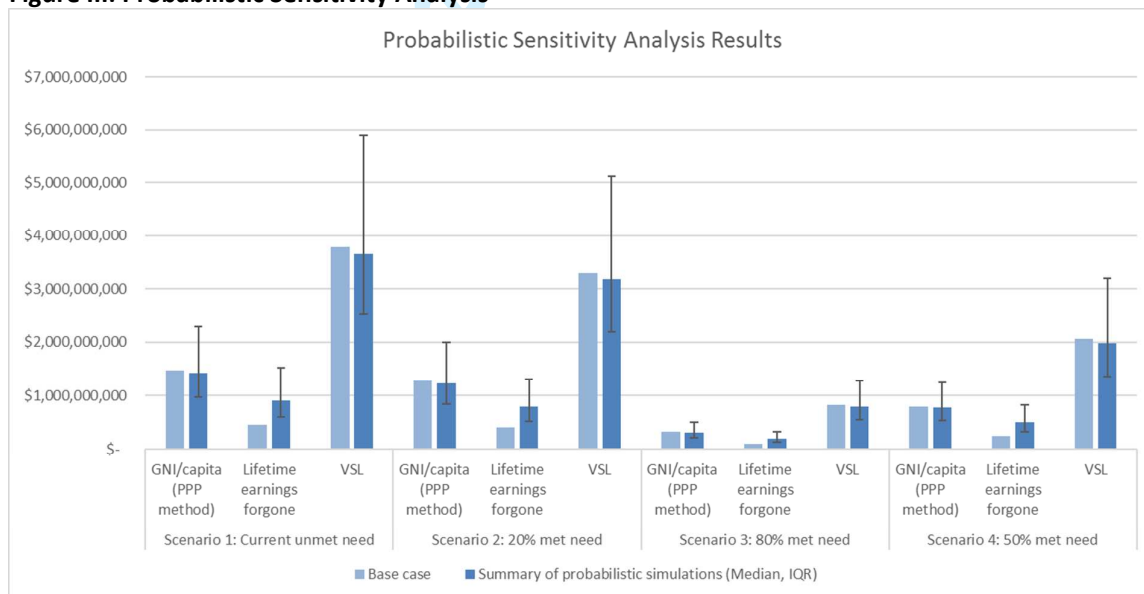


Figure III: Probabilistic Sensitivity Analysis



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Supplementary material for:

The Economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone

For peer review only

1
2
3 Supplementary file I
4

5 **Additional information on methods**
6

7 **Productive value of DALYs lost due to morbidity**
8

9 DALYs are useful tools for estimating health benefit as they combine dimensions of quality and
10 quantity of life.³¹ Yet productivity losses are clearer for mortality, beginning in full upon death, than
11 for morbidity, where a 0.5 morbidity DALY weight, for example, does not necessarily reflect a 50%
12 decrease in productivity. Whilst it is clear that a person becomes economically inactive upon death,
13 it is not so apparent how disability will affect productivity. For example, untreated cataracts can
14 result in severe visual impairment. The DALY weight for blindness due to cataracts is 0.6,³² but this
15 does not analogously suggest that productivity will also be reduced by 60%. The extent to which
16 morbidity affects economic productivity will be influenced by the nature of the morbidity and its
17 impact on employment, alongside contextual factors such as the potential for workplace
18 adaptations, for example.
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Supplementary table I

Possible VSL values for Sierra Leone

	Value	Method	Citation
1)	\$ 1,027,763	VSL of USA*(GNI per capita of USA/GNI per capita of Sierra Leone) ^{0.55} (0.55 = income elasticity of VSL suggested by Viscusi and Aldy (2003))	[1]
2)	\$ 577,000	Primary study from Sierra Leone examining transport choice to airport	[2]
3)	\$ 160,140	120*GDP/capita	[3]
4)	\$ 90,700	As (1), with higher elasticity as suggested by Hammit and Robinson (2009) (elasticity=1)	[1 4]

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Supplementary table II: Probabilistic sensitivity analysis parameters

Parameter	Modelled value (SE)	Lower bound	Upper bound	Distribution (if included in PSA)	Source
Discount rate	5%	0%	10%		
GNI/capita (PPP) (US \$)	1,919				[1]
Value of a statistical life (US \$)	90,700				[2]
Current met surgical need	92.1% (.029)			Normal	[3]
Months worked agriculture: Men	6	5	8	Uniform	[4]
Months worked agriculture: Women	6	4	8	Uniform	[4]
Monthly salary when employed in agriculture: Men (Leone)*	251306 (15221)			Gamma	[4]
Monthly salary when employed in agriculture: Women (Leone)	364881 (212265)			Gamma	[4]
Months worked non-agriculture: Men	12	9	12	Uniform	[4]
Months worked non-agriculture: Women	12	9	12	Uniform	[4]
Median monthly salary non agriculture: Men	515464 (47493)			Gamma	[4]
Median monthly salary non agriculture: Women	635594 (112102)			Gamma	[4]
Proportion of labour force in waged industry or self employed: Men**	0.16	0.12	0.2	Uniform	[4]
Proportion of labour force in waged industry or self employed: Women**	0.14	0.105	0.175	Uniform	[4]
Proportion of labour force in family farm/business: Men**	0.37	0.2775	0.4625	Uniform	[4]
Proportion of labour force in family farm/business: Women**	0.37	0.2775	0.4625	Uniform	[4]
DALY Calculation					
Constant	0.1658				
Age weighting (K)	0				
DALY Weights					
Fractures	0.19				[5]
Cataracts	0.03				[5]
Hernia	0.01				[5]
Obstetric fistula	0.34				[5]
Urethral stricture	0.07				[5]
*Mean and SE used for base case and PSA modelling					
**Proportion not in labour force defined as (1-proportion in labour force)					

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The Macro-economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone: A retrospective economic analysis

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The Macro-economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone: A retrospective economic analysis

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3 and wrote the initial draft of the manuscript. This was critically revised by AL, CL, TK and HB.
4 All have approved the final draft.
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Abstract

Objectives: The Lancet Commission on Global Surgery estimated that low and middle-income countries (LMICs) will lose an estimated cumulative loss of US\$12.3 trillion from gross domestic product (GDP) due to the unmet burden of surgical disease. However, no country specific data currently exists. We aimed to estimate the costs to the Sierra Leone economy from death and disability which may have been averted by surgical care.

Design: We used estimates of total, met and unmet need from two main sources - a cluster randomised, cross-sectional, countrywide survey and a retrospective, nationwide study on surgery in Sierra Leone. We calculated estimated disability-adjusted life years (DALYs) from morbidity and mortality for the estimated unmet burden and modelled the likely economic impact using three different methods – Gross National Income (GNI) per capita, lifetime earnings foregone, and value of a statistical life.

Results: In 2012, estimated, discounted lifetime losses to the Sierra Leone economy from the unmet burden of surgical disease was between \$1.1-3.8 billion, depending on the economic method used. These lifetime losses equate to between 23%-100% of the annual GDP for Sierra Leone. 80% of economic losses were due to mortality. The incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80% were calculated to be between US\$360 million – US\$2.9 billion.

Conclusion: There is a large economic loss from the unmet need for surgical care in Sierra Leone. There is an immediate need for massive investment to counteract on-going economic losses.

Article Summary

Strengths and limitations of this study

- The Lancet Commission on Global Surgery estimated cumulative losses from unmet surgical need of US\$12.3 trillion globally. This is the first country-specific study to estimate macroeconomic losses.
- Estimates of unmet need in this study are based on previous studies. It is not possible to be certain exactly what the unmet surgical need is.
- Likewise, true death and disability averted is impossible to be accurately determined and is based on estimates.
- All modelling strategies have their limitations, especially in resource-poor settings. Therefore we used three different approaches for comparison.

Introduction

Although once described as the “neglected stepchild of global health”,¹ surgery is increasingly being recognised as an indivisible, indispensable part of health care.² Currently, surgical disease accounts for an estimated 33% of the global burden of disease³, with an estimated 5 billion people have no access to safe, affordable surgical care and anaesthesia when needed⁴ and an estimated 143 million additional procedures needed in low and middle-income countries (LMICs) to save lives and to prevent disability.⁵ Surgical access is weakest in low-income countries.⁶ Although traditionally thought of as an expensive intervention, cost-effectiveness analyses have shown that surgery – both individual procedures and surgical platforms - are cost-effective when compared with other widely implemented health interventions⁷.

A number of studies have shown the profound economic impact on individuals and households resulting from untreated surgical conditions, with resulting death and disability.^{8,9} However, treatment of such conditions can improve the quality of life, household income as well as social status.¹⁰ Reducing deaths and disability from road traffic accidents alone in LMICs to the level of high income countries would result in a potential economic saving of US\$758-786 billion per year.¹¹ If there is no accelerated urgent scale up of surgical services, LMICs are estimated to lose a cumulative US\$12.3 trillion to their economies over the next 15 years.⁵

To date, there have been no country specific estimates of the economic costs resulting from loss of productivity due to death and disability from surgically treatable disease. Sierra Leone has been estimated to have a high burden of surgical disease, with a household survey suggesting that 25% of deaths in the previous year may have been averted by timely surgical intervention, and 25% of respondents claiming to have a surgical condition requiring attention.¹² Results from a national survey reported that there were 24,152 operations in Sierra Leone in 2012 across all hospitals (government and private) amounting to a national average of 400 operations per 100,000. This amounts to approximately 8% of surgical disease treated and 92% untreated. Our aim was to estimate the likely impact on the Sierra Leonean GDP resulting from this untreated surgical disease.

This study is carried out the context of slow improvements in health and economic indicators for Sierra Leone compared to other West African countries. Although life expectancy at birth increased from 41 to 51 years between 2002 and 2014, this remains the lowest life expectancy of any country assessed by the World Health Organization¹³. Malnutrition, communicable diseases, and poor maternal and child health services cause substantial mortality and morbidity each year¹⁴. The country has a growing and youthful population driven by a high total fertility rate of almost 5 children per woman, yet a small and largely agrarian economy underutilises this potential of its workforce with an estimated 60% youth unemployment attributable to poor educational outcomes, a lack of private sector jobs, and low pay¹⁵. Sierra Leone ranks 179 out of 188 countries included in the United Nations Development Programme’s Human Development Index, a composite ranking of health, educational, and economic outcomes by country¹⁶.

Methods

Disability Adjusted Life Years

The disability adjusted life year (DALY) is a composite measure of health quantity and quality which seeks to capture the negative consequences of premature mortality alongside burden from morbidity for the duration of an illness:

$$DALYs = YLD + YLL \quad (1)$$

$$YLD = I \times D \times DW \quad (2)$$

$$YLL = N \times LD \quad (3)$$

Where YLD is the number of years lost due to disability, I the incidence of a condition, D the duration of illness, DW the disability weight, YLL the years of life lost, N the number of deaths from a condition, and LD the life expectancy at age of death. DALYs are sometimes weighted differently according to the age at which a person dies, in theory to reflect societal values around death at younger age. This is a controversial topic in the calculation of DALYs and, as in WHO GBD studies since 2001, we do not apply age weighting in this analysis. We used local life expectancies from the World Health Organisations Life Table for Sierra Leone in 2012¹³ and disability weights published by the Global Burden of Disease (GBD) Study.¹⁷

Details of all operations performed in Sierra Leone in 2012 from every surgical provider was obtained from a nationwide, retrospective study.¹⁸ Data were excluded if there was no recorded age for the patient, or no recorded operation. The remaining records were then analysed. For each operation, we used a weighting system used by previous authors^{19,20} to determine the likely threat to life without treatment, the likelihood of permanent disability, and the likely efficacy of treatment (Table I). Operations were deemed to either avert death or disability as in Table II. Weights for each operation were estimated using a Delphi method of local doctors and experts in each field. Operations were weighted differently depending on whether they were “emergency” or “planned” operations. Those where it was unclear whether it was performed as a planned or an emergency operation, were weighted as for a “planned” operation. Assumptions for each operation are shown in Table II. Disability weights for conditions primarily causing disability were obtained from the Global Burden of Disease Study.¹⁷

Methods for calculating economic losses

A number of methods are available to calculate economic losses due to preventable health conditions, and we opt to take three approaches which are simple and transparent in nature.

Acknowledging the breadth of literature in this area, we use three different approaches to estimate productivity losses from unmet surgery need: two applying the human capital approach (HCA), firstly using inputs of GDP/capita, and secondly lifetime earnings forgone, alongside a method incorporating the value of a statistical life.

Both HCA approaches use national accounts or workforce participation and earnings data, and do not require extensive assumptions around the structure of the Sierra Leonean economy. These methods may therefore underestimate economic losses because they do not capture dynamic effects of reductions in morbidity or mortality, for example the economic productivity from additional children of persons whose death is delayed by surgery. The methods are consistent with the growing consensus in health economic evaluation that the societal perspective should be considered where possible to give a more accurate reflection of true economic losses to society, outside of direct health expenditure.²¹

The value of a statistical life (VSL) is the amount of money a person or society is willing to spend to save one life, and is commonly used by public bodies to value lives saved in cost-benefit analyses of health, transport or environmental projects.²² Data often comes from the labour market, where individuals sometimes make decisions that involve a trade-off between financial rewards and an

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3 increased risk of premature mortality. Economists use this revealed preference for risk to calculate
4 their VSL, reflecting the amount individuals are willing to pay to avert the risk of dying. For example,
5 if a welder on an oil rig was willing to accept a pay cut of £1,000 to work on land where the risk of
6 death was 0.001 lower, their VSL would be £1 million (£1,000/0.001). VSL estimates are often larger
7 than production-based measures of welfare losses (including the HCA), but fit better into welfare
8 economic frameworks because they allow the worth of individuals to be greater than their wage
9 rate.

10
11 We present economic losses both as an absolute number for income loss discounted to \$USD 2014
12 and as a percentage of gross domestic product (GDP), however we note caution in interpreting the
13 latter. Household earnings (and subsequent consumption) are elements of GDP calculations,
14 alongside aggregate government expenditure and business investment, amongst others. As
15 elsewhere in the literature,²³ we use the comparison between projected losses and actual GDP as a
16 useful relative frame to understand the large numbers produced by this model. However, we
17 emphasise that these are not directly causal and, in fact, may understate the direct effect of unmet
18 surgery need on GDP. Finally, we compare figures to the 2014 GDP of Sierra Leone due to the
19 anticipated negative impact of Ebola virus disease (EVD) on the Sierra Leonean economy²⁴.

21 **Modelling approach**

22 The need for surgery in Sierra Leone was calculated from two cluster randomised, cross-sectional,
23 countrywide surveys.^{12,25} First, we generate a counterfactual scenario where all annual mortality and
24 disability is avoided by assuming current met need is 8%, as estimated by Bolkan et al¹⁸ although this
25 is likely to be a conservative estimate. Then we present different scenarios of met need according to
26 published studies and benchmarks, aggregating reductions in mortality and morbidity separately.

27
28 The literature has not reached consensus on how to estimate productivity losses due to morbidity.²²
29 We take a pragmatic approach and obtain condition-specific data from the literature to estimate the
30 proportion of persons with surgically treatable conditions who were unable to work following the
31 development of a condition (Table II). Where no evidence of productivity effects are noted, we take
32 a conservative approach and assume that untreated persons do not suffer productivity losses.
33 Further information is provided in supplementary file I.

34 **Estimation of Economic losses**

35 We use three methods to estimate economic losses:

36 **1) Gross national income per capita**

37 A common application of the HCA, recommended by the WHO Commission on Macroeconomics and
38 Health, is to use Gross National Income per capita to estimate the potential economic gains from
39 gaining an additional year of life.²⁶ This approach has been applied elsewhere to estimate economic
40 gains and losses of health interventions. Although the GNI/capita approach may undervalue benefits
41 from averting a DALY as it does not account for externalities on the wider labour market or care
42 required from family members, the method is transparent and broadly accepted in the literature.²²
43 Thus, GNI/capita approximates the economic value that the average individual adds to a society per
44 year and we simply multiply GNI/capita by the number of DALYs averted in each scenario of met
45 surgical need.

46 **2) Lifetime earnings forgone**

The GNI/capita approach does not necessarily equate to the majority of individuals' economic productivity, particularly in unequal economies such as Sierra Leone, where few very productive individuals may bias mean earning estimates. Therefore we calculate the present value of lifetime earnings (PVLE) forgone for each age category, slightly adapting the model presented in Menzin et al.²⁷:

$$PVLE_{paid(i,j,k)} = \sum_{i=s_j}^{n_j} \frac{(l_{i,j,k} * w_{i,j,k})}{(1+r)^{i-s_j}} \quad (4)$$

Where the estimated losses for a cohort of persons with age i , gender j , working in employment sector k , and with life expectancy s_j , are a weighted average of their economic activity, l , and wage rate w . We split each gender into five age groups, driven by the availability of data on avertable mortality and morbidity, and use the midpoint of each strata to estimate years of productive life remaining.

We use data from the nationally representative 2011 Sierra Leone integrated household survey (SLIHS)²⁸ to obtain estimates of labour force participation by gender. We estimate the proportion of the population not in the labour force, the proportion employed in agriculture, and the proportion in other waged industry. For both employed groups, we use SLIHS data to calculate the number of hours worked per year and apply earnings and salary data to estimate total annual earnings.

3) Value of a statistical life

A number of methods exist to calculate the VSL in Sierra Leone, which are briefly summarised in supplementary table I. For our main analysis we use \$90,700 as calculated for sub-Saharan Africa by Robinson and Hammit.²⁹ We follow Alkire et al³⁰ and convert this VSL into its annualised equivalent, the value of a statistical life-year (VSLY), for use with DALYs. Here we assume that the VSL is analogous to an annuity, giving a constant stream of income of \$31,415 per year (5% discount rate). Consistent with DALY calculations we do not apply age weighting to this value so assume it remains constant throughout a lifetime. The use of Sierra Leonean data negates the re-scaling of VSL from the USA, as elsewhere.^{29,31}

Discount Rate: The choice of discount rate can have a large impact on the results of an economic analysis, particularly when benefits or costs occur a long time after initial expenditure.³² We use a discount rate of 5% on costs and benefits. We explore the effect of higher discount rates in a sensitivity analysis.

Uncertainty and sensitivity analyses: We use a deterministic sensitivity analysis to explore methodological uncertainty stemming from the choice of discount rate, exploring a zero discount rate, 3% as per guidelines, and 8.7% to mirror the local inflation rate. We carry out a multivariate probabilistic sensitivity analysis with 1000 Monte Carlo simulations of a number of variables simultaneously to assess the impact of parameter uncertainty on model predictions, and present included parameters and distributional assumptions in supplementary table II

Results

Met need in 2012

Out of the 24,152 operations recorded as being performed in Sierra Leone in 2012, 46% were excluded – 5,672 because of a lack of detail about the operation and 5,415 because there was no age recorded. We assumed that the 54% analysed were representative of the unmet need. 6,141 of

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3 the remaining operations were death averting, and 6,924 were disability averting (Table III).
4 Accounting for the probability of success in death-averting operations, 2,219 deaths were averted
5 through surgical intervention in 2012 (Table IV).
6

7 **Health losses due to unmet need**

8 Assuming that the 24,152 operations recorded in 2012 represent 7.9% of met surgical need in Sierra
9 Leone,¹⁸ we estimate that unmet surgical need in 2012 resulted in 766,606 DALYs forgone: 606,981
10 DALYs lost due to mortality and 159,625 due to morbidity. If surgical provision could be increased to
11 80% in line with the recommendations of The Lancet Commission on Global Surgery, an additional
12 599,953 DALYs would be averted compared to 2012 provision. Reaching the goal of 50% provision
13 would avert an additional 349,972 DALYs, whilst the pragmatic target of 20% provision would result
14 in 99,992 additional DALYs averted.
15

16 **Economic losses**

17 Figure I presents estimated discounted economic losses from unmet surgery need. As anticipated,
18 using different approaches to estimate losses, resulted in vastly different figures. The value of a
19 statistical life approach gave the highest figure: current economic losses due to unmet surgery need
20 were estimated to be \$3.8 billion (all monetary figures presented as 2012 USD), equivalent to 107%
21 of Sierra Leone's GDP in 2012. The GNI/Capita approach put forward by the WHO Macroeconomic
22 Commission gave the next highest figure of \$1.4 billion (42% of 2012 GDP), whilst the lifetime
23 earnings forgone method gave an estimate of \$1.1 billion (31% of 2012 GDP). Economic losses due
24 to mortality contributed to around 80% of total economic loss from unmet need across all measures.
25 Finally, table V presents the incremental losses that would be averted if surgical provision were to be
26 scaled up to each of the three target scenarios.
27
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29 **Sensitivity analyses**

30 Figure II displays results from a one-way sensitivity analysis, analysing the change in estimates of
31 unmet need as model parameters are varied in isolation. Estimates are particularly sensitive to
32 assumptions of current unmet need and whether the productivity estimates consider morbidity in
33 addition to mortality. Assumptions of earnings do not make a substantive difference to estimates
34 using the lifetime earnings forgone method.
35

36
37 Figure III displays the results of a probabilistic sensitivity analysis alongside base case estimates,
38 whilst error bars illustrate the 25th and 75th quartiles of Monte Carlo model runs. When accounting
39 for parameter uncertainty in the PSA, the model still predicts substantial economic losses due to
40 unmet surgical need. Of all probabilistic simulations, 38% of estimates were greater than the
41 deterministic estimate. The variability of VSL simulation estimates is between 61% and 73% greater
42 than that of human capital approaches.
43

44 **Discussion**

45
46 In 2013, the Lancet Commission on Investing in Health argued that investing in healthcare in LMICs
47 produced profound returns on investment of between \$9-20 for every dollar invested.³³ The
48 question thus arose as to whether investment in the provision of surgical services to avert death and
49 disability would give a similar financial return on investment. This question was addressed by the
50 Lancet Commission on Global Surgery which presented data on both the economic impact of
51 untreated disease and the financial commitment required to scale up surgical services. Alkire et al
52 calculated projected economic losses in LMICs from a variety of surgical conditions using the Value
53 of Lost Output approach of up to 2.5% of annual GDP and 17% of 2010 GDP if a Value of Lost
54 Welfare approach was used.³⁴ Verguet et al³⁵ modelled the possible scale up of surgical services in
55 low and middle income countries for the Lancet Commission on Global Surgery target of 5000
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3 operations per 100,000 population per year and calculated that costs of US\$300-420 billion would
4 need to be met to achieve scale up over the years 2012-2030, representing 4-8% of total annual
5 health expenditure. This large investment in scaling up surgical services across 88 LMICs was positive
6 when compared with the \$12.3 Trillion loss to economic growth in these countries if surgical service
7 development was neglected. The Lancet Commission on Global Surgery data presented a similar
8 picture presented to the Lancet Commission on Investing in Health – investing in surgical care was
9 beneficial and produced significant economic returns on investment.
10

11 The few studies that have been published on the macroeconomic impact of surgical disease in low-
12 and middle-income countries, all show significant costs to national economies.^{11,34} This study
13 demonstrates significant estimated costs to the economy of Sierra Leone from untreated surgical
14 disease. It is the first single country study and also represents a move away from modelled data to
15 the use of primary surgical data for an estimation of the economic impact of untreated disease. The
16 economic impact of untreated surgical disease in Sierra Leone is significant. In 2012, the estimated
17 cumulative loss to the Sierra Leone economy from the unmet burden of surgical disease was
18 between \$1.1-3.8 billion, depending on the economic method used. This equates to between 23%-
19 100% of the 2012 GDP for Sierra Leone. 80% of economic losses were due to mortality. The
20 incremental losses averted by scale up of surgical provision to the Lancet Commission target of 80%
21 were calculated to be between US\$360 million – US\$2.9 billion, accepting that the Lancet
22 Commission target was for 80% access to the Bellwether procedures, not for all surgery.
23

24
25 There are a number of limitations to this study. Firstly, we had to discard 46% of the surgical data
26 because it was incomplete. As a result, we worked with only 54% of the surgical data, which may
27 not have been fully representative and may have skewed the results. We assumed that this 54%
28 accounted for the 7.9% of met need, and calculated unmet need based on this, although of course, if
29 we had a full complement of data, the met need and hence the unmet need would have been
30 significantly greater.
31

32 Where data was absent, for example when a patient's age was recorded but not their gender, we
33 used complete data observations to weight how these were distributed across groups at the lowest
34 level of aggregation available, e.g. by age group. If observations were missing not at random (type-2
35 error), this could introduce bias into our estimates. We assumed operations not listed as either
36 "emergency" or "planned" were planned, so as to create a conservative estimate of the overall
37 economic impact. In practice, many of these may have been emergencies and would have made the
38 resulting economic losses even greater. We assumed that the same proportion of met and unmet
39 need was uniform across all operations. However, it may be that the proportion of met: unmet need
40 may be higher for certain operations because of the nature of the pathology and the urgency for
41 example, free healthcare for pregnant women might mean that the ratio of met: unmet need is
42 higher for caesarean sections than it is for emergency laparotomy. We also assumed that treating a
43 treatable condition would return the patient back to full economic productivity, although this may
44 not be the case.
45

46
47 There is substantial variation between estimates of economic losses depending on the methodology
48 used, despite all methods using an equivalent estimate of DALYs attributable to unmet need. The
49 VSL method places the greatest value on each DALY incurred and by definition leads to the largest
50 estimate of economic loss. The human capital approaches, using estimates of GNI/capita and
51 lifetime earnings foregone, place a small cost on the loss of each DALY, and produce smaller
52 estimates. In addition, economic losses estimated here do not consider the value of unpaid or
53 domestic work because of uncertainty in assumptions required, and because these do not form part
54 of many estimates of GDP. In addition, our use of financial measurements of economic productivity
55 is a limitation in the largely agrarian economy of Sierra Leone. Other metrics, which cannot be easily
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3 valued in financial terms such as food insecurity or the distribution of labour within the household,
4 may capture potentially important aspects of economic productivity. Omitting these factors
5 makes our model more conservative and we are likely to underestimate total economic losses, with
6 a greater underestimation occurring in female groups.
7

8 Averages (mean values) are used to parameterise the model, and we therefore do not account for
9 heterogeneity in estimates except for between genders and the age at which surgery was required.
10 Other literature has shown a notable correlation between propensity for ill health and income,
11 particularly in low- and middle-income contexts such as this study, and this model does not account
12 for this. The lifetime earnings estimates in the human capital approach may overstate losses, and
13 therefore assume that premature mortality or morbidity causes a lifetime's impact to the economy.
14 With more data, we could have used a friction cost method to be more conservative, however, the
15 lost earnings estimates are the lowest produced in this study.
16

17 Despite these limitations which are prevalent in much of the global surgical literature, we have
18 provided the first national study of economic losses based on as much data as is currently available
19 for Sierra Leone. This suggests massive economic losses, much of which may be avertable by the
20 provision of timely, surgical care. What is now required is the development of a costed national
21 surgical plan as recently undertaken in Zambia. In the case of Sierra Leone, the necessary investment
22 might be more than the Lancet Commission on Global Surgery figure of 4-8% of total annual health
23 expenditure as there is likely to be a large initial capital outlay as well as a very significant necessary
24 investment in the surgical workforce. Only then will we be able to compare this required investment
25 with our economic loss figures to quantify the return on surgical system investment in terms of lives
26 saved and disability averted.
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Tables and Figures

Table I: Weightings definition

Weighting given	Risk of death or permanent disability	Treatment efficacy
0	Condition fatal or permanently disabling <5% of the time	<5% chance of permanent cure
0.3	Condition fatal or permanently disabling 5-50% of the time	5-50% chance of permanent cure
0.7	Condition fatal or permanently disabling 50-95% of the time	50-95% chance of permanent cure
1	Condition fatal or permanently disabling >95% of the time	>95% chance of permanent cure

Table II: Delphi Weights for Primarily death-averting and primarily disability-averting operations with assumptions on earnings.

Primarily death averting	Threat to life	Treatment efficacy	Risk of permanent disability	Assumption on earnings
Appendectomy	0.7	1.0		
Caesarian section	0.3	0.7		
Cervical or vaginal laceration	0.1	1.0		
Chest tube	1.0	1.0		
Dilatation and curettage	0.3	0.7		
Hernia repair (emergency)	0.7	1.0		
Hysterectomy	0.3	0.7		
Laparotomy – emergency	1.0	0.7		
Laparotomy – elective	0.3	0.3		
Malignancy	1.0	0.3		
Manual placenta removal	0.3	0.7		
Neonatal surgery (emergency)	1.0	0.7		
Repair of ruptured uterus	1.0	1.0		
Ectopic pregnancy	0.7	1.0		
Tracheostomy	1.0	0.7		
Amputation of limb	1.0	0.7		
Primarily disability averting				
Cataract surgery		0.7	0.7	60% lifetime earnings lost
Cleft lip repair		0.7	1.0	No impact (no literature found)
Cystostomy		1.0	0.7	No impact (no literature found)

Fracture		0.7	0.7	88% of earnings lost for one year
Hernia repair (planned/unknown)		0.3	1.0	18% (16-20%) lifetime earnings lost
Neonatal surgery (planned/unknown)		0.7	0.7	No impact (no literature found)
Obstetric fistula repair		0.7	1.0	97% lifetime earnings lost
Urethral stricture dilation		0.3	1.0	No impact

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Table III: Total number of DALYs averted by operation

Primarily death averting	Number of operations in 2012
Amputation	234
Appendectomy	1,114
Caesarian section	2,646
Cervical or vaginal laceration	24
Chest tube	35
Dilatation and curettage	508
Hernia repair (emergency)	166
Hysterectomy (all)	218
Laparotomy (all)	815
Malignancy	173
Manual placenta removal	65
Necrotomy	1
Neonatal surgery (emergency)	13
Manual placenta removal	8
Salpingectomy for ectopic pregnancy	10
Ectopic pregnancy	103
Tracheostomy	8
Primarily disability averting	
Cataract surgery	2,242
Cleft lip repair	2
Cystectomy	16
Fracture	964
Hernia repair (planned/unknown)	3,435
Neonatal surgery (planned/unknown)	5
Obstetric fistula repair	201
Urethral stricture dilation	59
Total	13,065

Table IV: Summary of met surgical need in 2012

Age (years)	Deaths averted in 2012	Mortality DALYs averted due to surgery in 2012 (YLL)	Morbidity DALYs averted due to surgery in 2012 (YLD)
1-4	58	1,073	293
5-15	214	3,877	741
16-19	278	4,936	566
20-33	778	13,086	2,225
34+	332	5,173	3,626

Table V: Incremental losses averted by scale up of surgical provision compared to current met need

Incremental economic losses averted	Scenario 2: 20% met need	Scenario 3: 80% met need	Scenario 4: 50% met need
GNI/capita (ppp)	\$191,900,891	\$1,151,405,348	\$671,653,120
Earnings forgone (YLY only)	\$60,154,488	\$360,926,928	\$210,540,708
Value of a statistical life approach	\$493,778,864	\$2,962,673,184	\$1,728,226,024

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3 **Figure I: Estimated discounted lifetime economic losses due to unmet surgery need by scenario**

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5 **Figure II: One way sensitivity analysis**

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7 **Figure III: Probabilistic Sensitivity Analysis**

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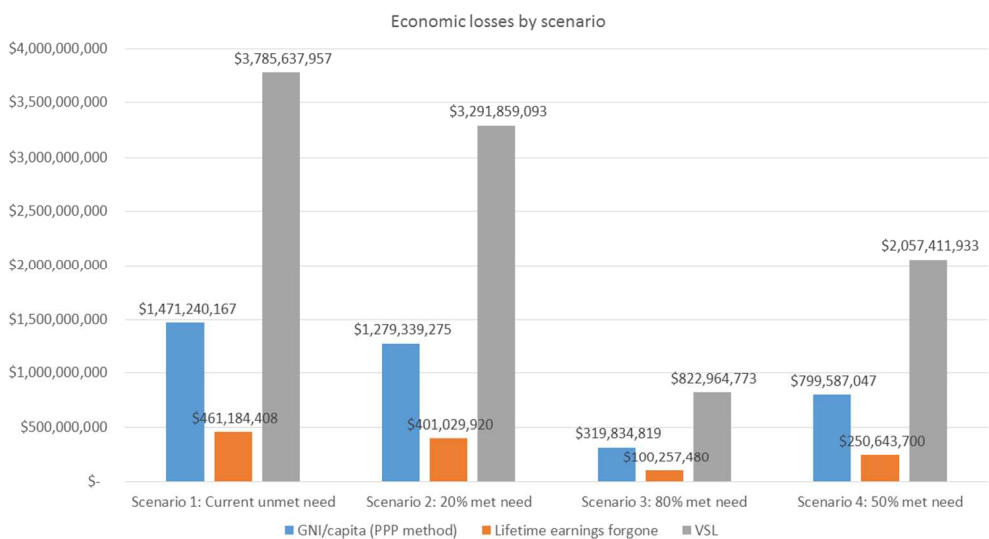


Figure I: Estimated discounted lifetime economic losses due to unmet need by scenario

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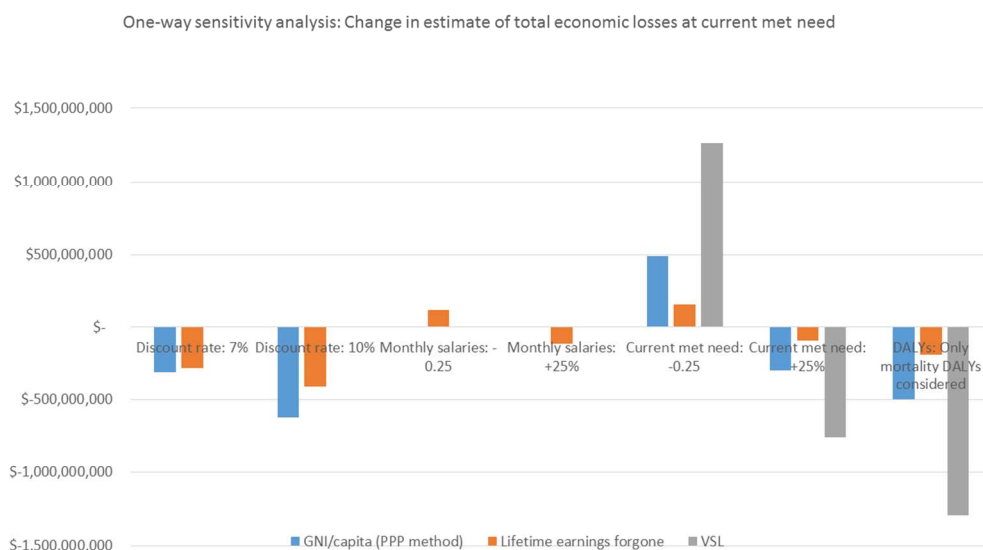


Figure II: One way sensitivity analysis!! †

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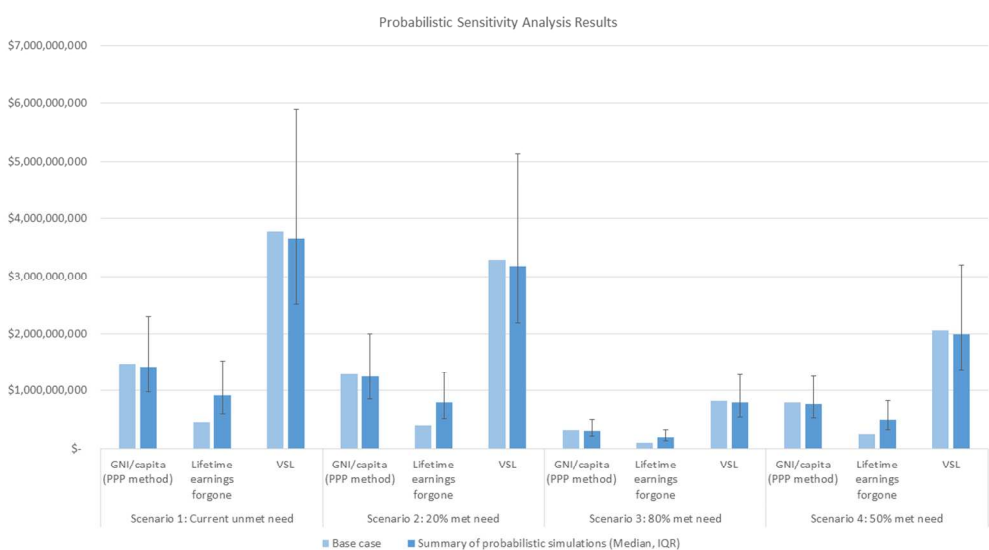


Figure III: Probabilistic Sensitivity Analysis!!

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Supplementary material for:

The Economic Costs of the Unmet Burden of Surgical Disease in Sierra Leone

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3 Supplementary file I
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5 **Additional information on methods**
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7 **Productive value of DALYs lost due to morbidity**
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10 DALYs are useful tools for estimating health benefit as they combine dimensions of quality and
11 quantity of life.³⁶ Yet productivity losses are clearer for mortality, beginning in full upon death, than
12 for morbidity, where a 0.5 morbidity DALY weight, for example, does not necessarily reflect a 50%
13 decrease in productivity. Whilst it is clear that a person becomes economically inactive upon death,
14 it is not so apparent how disability will affect productivity. For example, untreated cataracts can
15 result in severe visual impairment. The DALY weight for blindness due to cataracts is 0.6,³⁷ but this
16 does not analogously suggest that productivity will also be reduced by 60%. The extent to which
17 morbidity affects economic productivity will be influenced by the nature of the morbidity and its
18 impact on employment, alongside contextual factors such as the potential for workplace
19 adaptations, for example.
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Supplementary table I

Possible VSL values for Sierra Leone

	Value	Method	Citation
1)	\$ 1,027,763	VSL of USA*(GNI per capita of USA/GNI per capita of Sierra Leone) ^{0.55} (0.55 = income elasticity of VSL suggested by Viscusi and Aldy (2003))	[1]
2)	\$ 577,000	Primary study from Sierra Leone examining transport choice to airport	[2]
3)	\$ 160,140	120*GDP/capita	[3]
4)	\$ 90,700	As (1), with higher elasticity as suggested by Hammit and Robinson (2009) (elasticity=1)	[1 4]

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4. Robinson LA, Hammitt JK. The value of reducing air pollution risks in sub-saharan Africa. *Lisa A Robinson* 2009:5

Supplementary table II: Probabilistic sensitivity analysis parameters

Parameter	Modelled value (SE)	Lower bound	Upper bound	Distribution (if included in PSA)	Source
Discount rate	5%	0%	10%		
GNI/capita (PPP) (US \$)	1,919				[1]
Value of a statistical life (US \$)	90,700				[2]
Current met surgical need	92.1% (.029)			Normal	[3]
Months worked agriculture: Men	6	5	8	Uniform	[4]
Months worked agriculture: Women	6	4	8	Uniform	[4]
Monthly salary when employed in agriculture: Men (Leone)*	251306 (15221)			Gamma	[4]
Monthly salary when employed in agriculture: Women (Leone)	364881 (212265)			Gamma	[4]
Months worked non-agriculture: Men	12	9	12	Uniform	[4]
Months worked non-agriculture: Women	12	9	12	Uniform	[4]
Median monthly salary non agriculture: Men	515464 (47493)			Gamma	[4]
Median monthly salary non agriculture: Women	635594 (112102)			Gamma	[4]
Proportion of labour force in waged industry or self employed: Men**	0.16	0.12	0.2	Uniform	[4]
Proportion of labour force in waged industry or self employed: Women**	0.14	0.105	0.175	Uniform	[4]
Proportion of labour force in family farm/business: Men**	0.37	0.277 5	0.4625	Uniform	[4]
Proportion of labour force in family farm/business: Women**	0.37	0.277 5	0.4625	Uniform	[4]
DALY Calculation					
Constant	0.1658				
Age weighting (K)	0				
DALY Weights					
Fractures	0.19				[5]
Cataracts	0.03				[5]
Hernia	0.01				[5]
Obstetric fistula	0.34				[5]
Urethral stricture	0.07				[5]
*Mean and SE used for base case and PSA modelling					
**Proportion not in labour force defined as (1-proportion in labour force)					

1. World Bank. Country Profile: Sierra Leone. Secondary Country Profile: Sierra Leone 2016. <http://www.worldbank.org/en/country/sierraleone>.
2. Robinson LA, Hammitt JK. The value of reducing air pollution risks in sub-saharan Africa. Lisa A Robinson 2009:5
3. Alkire BC, Shrimme MG, Dare AJ, et al. Global economic consequences of selected surgical diseases: a modelling study. Lancet Glob Health 2015;3 Suppl 2:S21-7 doi: 10.1016/s2214-109x(15)70088-4[published Online First: Epub Date] |.
4. Statistics Sierra Leone (SSL). Sierra Leone - Integrated Household Survey 2011, 2011.
5. World Health Organization. Global Burden of Disease 2004 Update: Disability Weights for Diseases and Conditions, 2004.

For peer review only

CHEERS Checklist**Items to include when reporting economic evaluations of health interventions**

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force*, provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: <http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp>

Section/item	Item No	Recommendation	Reported on page No/line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as “cost-effectiveness analysis”, and describe the interventions compared.	<u>1</u>
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	<u>3</u>
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	<u>4</u>
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	<u>5</u>
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	<u>5</u>
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	<u>5-7</u>
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	<u>5-7</u>
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	<u>5-7</u>
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	<u>7</u>
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	<u>5-7</u>
Measurement of effectiveness	11a	<i>Single study-based estimates:</i> Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	<u>N/A</u>



Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 2

	11b	<i>Synthesis-based estimates</i> : Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	<u>N/A</u>
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	<u>N/A</u>
Estimating resources and costs	13a	<i>Single study-based economic evaluation</i> : Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	<u>N/A</u>
	13b	<i>Model-based economic evaluation</i> : Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	<u>S-7</u>
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	<u>S-7</u>
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	<u>S-7</u>
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	<u>S-7</u>
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	<u>S-7</u>
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	<u>11-13</u>
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	<u>14</u>
Characterising uncertainty	20a	<i>Single study-based economic evaluation</i> : Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	<u>N/A</u>



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		of methodological assumptions (such as discount rate, study perspective).	
	20b	<i>Model-based economic evaluation</i> : Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	16
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	8-10
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	1
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	1

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: <http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp>

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