# Evaluating access improving interventions: An economic evaluation of surgical task-shifting for C-sections in Sierra Leone

# Running heading: Economic evaluation of surgical task-shifting for C-sections in Sierra Leone

Bryony Dawkins1, Bethany Shinkins2, Tim Ensor3, David Jayne4, Thomas Ashley5, Alex J. van Duinen6,7,8, Håkon A. Bolkan6,7,8, David Meads1

1 Academic Unit of Health Economics, Leeds Institute of Health Sciences, University of Leeds, Leeds, UK

2 Division of Health Sciences, Warwick Medical School, University of Warwick, Coventry, UK.

3 Nuffield Centre for International Health and Development, Leeds Institute of Health Sciences, University of Leeds, Leeds, UK

4 Leeds Institute of Medical Research at St James’s, University of Leeds, St James’s University Hospital, Leeds, United Kingdom

5 Masanga Hospital, Sierra Leone

6 Department of Public Health and Nursing, Norwegian University of Science and Technology (NTNU)

7 Clinic of Surgery, St Olav’s Hospital, Trondheim University Hospital, Trondheim, Norway

8 CapaCare, Trondheim, Norway and Freetown, Sierra Leone

Address for correspondence:

Bryony Dawkins

Academic Unit of Health Economics,

Leeds Institute of Health Sciences,

Worsley Building,

Clarendon Way,

Leeds LS2 9NL, UK.

b.dawkins1@leeds.ac.uk

## Abstract

Background: Access to safe, timely and affordable surgical care is lacking globally. Less than 6% of all surgical operations are carried out in low- and middle-income countries, where over a third of the world’s population lives.

CapaCare, an NGO operating in Sierra Leone, have developed a surgical training programme (STP) for Associate Clinicians based on principles of task-shifting to improve access. Interventions to increase health care access have the same value evidence requirements as new technologies but their evaluation presents methodological challenges as access is not routinely incorporated explicitly in economic evaluations.

### Objective:

To evaluate the cost-effectiveness of surgical task-shifting in Sierra Leone, implemented through the CapaCare STP, to increase provision C-Section.

Methods: We evaluated the impact of the STP on the provision of C-section and subsequent maternal and child outcomes, measured in DALYs, relative to the costs using a healthcare system perspective and decision-tree model parameterised using data from surgical logbooks, national data, and the literature.

Results: Results indicate that the surgical task-shifting programme in Sierra Leone would be considered cost-effective in increasing provision for C-section. It is cost saving (USD -16.77) and results in 2.14 DALYs averted, per women with an indication for C-section, due to avoidance of maternal and child deaths as well as reduced complications.

Conclusion: Investment in surgical task-shifting initiatives should be considered by policymakers as a potentially cost-effective way to increase access to quality surgical services. Future evaluations of access-increasing interventions should seek to capture the distributional impact of this strategy and system benefits.

## Key Points for Decision Makers

* Surgical task-shifting is a cost-effective way to improve maternal and child health outcomes when there is an indication for C-section.
* It also likely results in more equitable access to surgery, but these benefits are not captured by standard methods of cost-effectiveness analysis.
* Future evaluations of access-increasing interventions should seek to capture the distributional impact and system benefits.

## Declarations

### Conflicts of interest

BD, DGJ, BS, TE and DM have no conflicts of interest to declare. TA is the training coordinator and AVD and HB are unpaid board members for CapaCare.

### Funding

This study was undertaken as part of a PhD partially funded by Leeds Institute of Health Sciences, University of Leeds. No funding was received to undertake this study or to assist with the preparation of this manuscript.

## Data availability

All data used within the analysis are included in the published article and accompanying materials.

### Ethical Approval

Ethical approval was obtained in Sierra Leone from the Office of the Sierra Leone Ethics and Scientific Review Committee; and in the UK from the University of Leeds, School of Medicine Research Ethics Committee (reference **MREC 19-089).**

### Consent to participate

Not applicable

### Consent for publication (from patients/participants)

Not applicable

### Code availability

Not applicable

### Author contributions

BD contributed to the research plan, the design of the study and methodology, developed the economic model, undertook the analysis, interpreted results, developed the write-up of the manuscript and was responsible for the submission and correspondence.

DM, BS, DGJ and TE are BD’s PhD supervisors and have contributed to the formulation of the research plan, the study methodology development, review and interpretation of results, and manuscript editing.

HB, AVD and TA have provided data to inform analysis and have contributed to the formulation of the research plan, the study methodology development, review and interpretation results, and manuscript editing.

All authors approved the final manuscript.

## Acknowledgements

The authors would like to thank all STP trainees and graduates for their careful completion of surgical logbooks which have provided a valuable data source for this study, and for their time to discuss their experience of the STP and subsequent surgical work in Sierra Leone which provided important context to inform the evaluation. We would also like to thank the CapaCare staff who provided accounts and other information to inform the costs of the programme.

## 1. Introduction

Access to safe, timely and affordable surgical care is lacking globally with 5 out of 7 people unable to access surgical care when they need it [1, 2]. Furthermore, less than 6% of all surgical operations are carried out in low- and middle-income countries (LMICs) where over a third of the world’s population lives, and a huge scale up in surgical services is needed urgently [3]. In Sierra Leone, a low-income country by World Bank classifications, opportunities for post-graduate surgical training are limited. Consequently, the trained surgical workforce is under severe pressure resulting in a shortage of surgical providers, limited access to quality surgical care across the country with most surgical providers concentrated in the capital city, Freetown, and poor health outcomes for conditions treatable by surgery [4].

Task-shifting, and task-sharing, are related approaches intended to help address the shortage of healthcare workers by re-distributing healthcare tasks among the available health workforce [5, 6]. Task-shifting and task-sharing are often used interchangeably in the literature although there are subtle differences between them, with the focus being on responsibilities and execution of tasks being shared in ‘task-sharing’ and the focus being on responsibility for some tasks shifting to a different cadre of healthcare professional in ‘task-shifting’ [7]. The term task-shifting is most commonly used in the literature and so we use this term through the rest of the article as a collective term for these approaches. Interest in task-shifting as a potential solution to shortage of surgical workforce has increased in recent years [8, 9]. Consequently, a number of initiatives have been introduced in LMICs [10]. However, while task-shifting may be useful in increasing surgical providers one concern has been around the impact on quality of care. Another issue is in the acceptability of surgical providers trained only in surgery without more extensive medical training [11].

CapaCare, an NGO operating in Sierra Leone, have developed a surgical training programme (STP) for Community Health Officers (CHOs), Medical Doctors (MDs) and Physician Assistants (PAs) based on the principles of task-shifting (more specifically, task-sharing), enabling non-specialist surgeons to perform some surgical duties. This should increase the supply of surgical care and improve access. The STP was launched in Sierra Leone in 2011, and up to 2022 has produced 70 graduates. Initially the STP accepted CHOs and MDs and since 2021 also PAs, with the majority (>95%) of graduates being CHOs and PAs, referred to collectively as Associate Clinicians (ACs) throughout the rest of the article. Additional details on the STP are published elsewhere [12, 13]. Current evidence on the CapaCare STP indicates that it is effectively increasing surgical provision in Sierra Leone and evidence on the quality of care provided shows that the care provided by STP graduates is non-inferior to that provided by medically trained surgeons in the country [12, 14, 15].

However, despite now being well established, the CapaCare STP has not yet been fully evaluated in terms of the resources required to run it, nor in terms of its cost-effectiveness as a means to increase provision of quality surgical care in Sierra Leone. This presents an opportunity to fill this evidence gap and provide evidence on the value of the STP in Sierra Leone to support its future scale up and sustainability, and it also presents an opportunity to explore the methodological issues around evaluating interventions which aim to increase healthcare access. Access-improving interventions have the same value evidence requirements as new technologies but economic evaluations of these are likely to present methodological challenges. In the context of the global goal to achieve universal healthcare coverage as part of the 2030 sustainable development goal agenda, the impact of interventions on healthcare access is becoming increasingly important to measure and evaluate [16-18].

As such this study sought to evaluate the CapaCare STP as a means to increase surgical provision through task-shifting. However, due to the complexity of evaluating the full range of surgeries provided by STP graduates, we focused on the provision of C-section as this procedure has the highest surgical volume among STP graduates. While there are many barriers to C-section including availability of theatres and limited referrals [19], a context specific study of barriers to surgery in Sierra Leone highlights financial constraints as being most important and availability of providers being the second issue [20]. In the case of C-section, the financial barriers are minimised due to national policy for free maternal care, making availability of surgical providers the most important barrier for C-section in this context. Consequently, the aim of this study was to undertake an economic evaluation of the CapaCare STP and its impact on provision of caesarean section (C-section) in Sierra Leone and to use this as a case study to highlight methodological challenges in appraising access enabling interventions.

## 2. Methods

### 2.1 Overview

A decision tree model was developed to capture a simplified patient pathway for women in need of a C-section in Sierra Leone. Costs and health outcomes were estimated based on provision of C-section in Sierra Leone with the CapaCare STP (i.e. with additional surgical provision from STP graduate ACs) and compared with estimates of what provision of C-section would be without the STP (i.e. where C-sections are only provided by medically trained surgeons) to determine the cost-effectiveness of the programme. In Sierra Leone, before the STP C-sections could be provided either by specialist surgeons and obstetricians, or by MDs who had undergone surgical training, referred to collectively as medically trained surgeons throughout the article. With the STP, C-sections could also be provided by STP graduate ACs. While MDs were permitted to join the STP, only 3 did so in the analysis period (up to 2018) and none of these contributed data to the surgical logbooks which provided data for analysis. As such, the analysis compares C-sections provided by medically trained surgeons with C-sections provided by medically trained surgeons plus STP graduate ACs. Costs were evaluated from the healthcare system perspective as this represents the most relevant perspective in Sierra Leone where legislation dictates that healthcare is provided free of charge for mothers and children under 5 years of age. Outcomes were measured in terms of disability adjusted life years (DALYs) avoided. A health economics analysis plan (available on request) was developed prior to transfer of data from CapaCare records (as per the data sharing agreement) and prior to any analysis. All analyses were undertaken using STATA Version 18 and Microsoft Excel.

### 2.2 Model structure

As the main way in which the STP affects maternal and child outcomes is through increased provision of (and therefore access to) surgery, and this has the most significant impact early in the treatment pathway, a decision tree model was developed for the analysis. A Markov model to capture longer-term impacts was considered, however this would add additional complexity which wasn’t considered feasible with the data available. Consequently, longer term impacts were incorporated as pay-offs within the decision tree. The model structure is shown in Figure 1. The model starts with a cohort of patients for whom a need for C-section has been identified. Flowing from left to right, it then models the patient pathway, including availability of C-section and subsequent costs and outcomes in the Sierra Leonean context with the STP and without the STP. C-sections can be planned or emergency. Planned C-sections are assumed to be available as it would not be possible to plan in advance if the service was not available. Emergency C-sections are those for which the need for C-section presents unexpectedly and consequently may or may not be available in the Sierra Leonean context. For each pathway, outcomes are categorised according to whether there are complications or not and death. It is assumed that if death occurs there are also complications, and this is accounted for in the calculation of costs and DALYs associated with each pathway. Maternal and child outcomes were modelled separately, using the same model structure shown in Figure 1 but parameterised according to risks of complications and death specific to mothers and babies and with relevant outcomes and costs. Outputs from the two models were then combined additively to estimate the overall effect for maternal and child health. Costs associated with the delivery were captured only in the maternal model to prevent double counting.



Figure 1: Model structure

### 2.3 Data sources and model parameters

All base case model parameters are presented in Table 1.

Table 1: Model parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Deterministic**  | **Distribution** | **Parameter 1\*** | **Parameter 2\*** | **Source** |
| Age (maternal) [Mean, SD] | 26 | Normal1 | 25.785 | 6.62 | Mean age, Logbook data |
| Expected births | 229482 | Fixed |  |  | estimated from population 2012 =6039000 (Statistics Sierra Leone, 2013) & crude birth rate =38 (The World Bank, 2025) [21, 22] |
| Maternal indication for c-section | 0.054 | - |  |  | Dumont, 2001 [23] |
| Annual patient cohort (expected need for caesarean) | 12392 | Fixed |  |  | expected births\*maternal indication for c-section |
| Proportion of c-sections planned [**α,** β] | 0.145 | Beta | 166 | 980 | Duinen et al., 2021 [24] |
| Proportion of c-sections emergency | 0.855 | - |  |  | 1-proportion planned |
| Estimated C-sections per year without STP | 4868 | - |  |  | Bolkan et al., 2015 [25] |
| Estimated C-sections per year with STP | 6885 | - |  |  | estimated based on Bolkan et al., 2015, Logbook data and CapaCare accounts [25] |
| Discount rate | 0.03 | Fixed |  |  | iDSI reference case |
| Probabilities - availability of c-section without STP |
| C-section available without STP [**α,** β] | 0.393 | Beta | 4868 | 7524 | Bolkan et al., 2015 [25] |
| Planned c-section (received)2 | 0.057 | - |  |  | Availability of c-section \* proportion planned |
| Emergency c-section | 0.943 | - |  |  | 1-p(planned c-section) |
| Emergency c-section received | 0.336 | - |  |  | Availability of c-section \* proportion emergency |
| Emergency c-section not received | 0.664 | - |  |  | 1-p(emergency c-section received) |
| Probabilities - availability of c-section with STP |
| C-section available with STP [**α,** β] | 0.556 | Beta | 6885.436 | 5506.564 | estimated based on Bolkan et al, 2015, Logbook data and CapaCare accounts [25] |
| Planned c-section (received)2 | 0.08 | - |  |  | Availability of c-section \* proportion planned |
| Emergency c-section | 0.92 | - |  |  | 1-p(planned c-section) |
| Emergency c-section received | 0.475 | - |  |  | Availability of c-section \* proportion emergency |
| Emergency c-section not received | 0.525 | - |  |  | 1-p(emergency c-section received) |
| Probability antepartum complications | planned C-section |
| Obstructed labour [**α,** β] | 0.166 | Beta | 29 | 146 | Duinen, 2020; supplement 2 [26] |
| Malpresentation/ transverse lie [**α,** β] | 0.057 | Beta | 10 | 165 | Duinen, 2020; supplement 2 [26] |
| Hypertensive disease/ Eclampsia [**α,** β] | 0.046 | Beta | 8 | 167 | Duinen, 2020; supplement 2 [26] |
| Foetal distress [**α,** β] | 0.006 | Beta | 1 | 174 | Duinen, 2020; supplement 2 [26] |
| Probability antepartum complications | emergency C-section |
| Obstructed labour [**α,** β] | 0.411 | Beta | 452 | 647 | Duinen, 2020; supplement 2 [26] |
| Antepartum haemorrhage [**α,** β] | 0.013 | Beta | 14 | 1085 | Duinen, 2020; supplement 2 [26] |
| Malpresentation/ transverse lie [**α,** β] | 0.054 | Beta | 59 | 1040 | Duinen, 2020; supplement 2 [26] |
| Hypertensive disease/ Eclampsia [**α,** β] | 0.03 | Beta | 33 | 1066 | Duinen, 2020; supplement 2 [26] |
| Foetal distress [**α,** β] | 0.056 | Beta | 61 | 1038 | Duinen, 2020; supplement 2 [26] |
| STP costs (USD) |
| Additional cost per C-section attributed to the STP | 2.012 | - |  |  | Calculated as: (Cost per graduate trained \* proportion of surgeries performed that are c-section)/ (average no. c-sections performed by STP graduates per year \* 5 years) (see Supplementary Appendix 1) |
| Procedure costs - Healthcare provider perspective (USD) |
| C-section performed by medically trained surgeon[*α, θ]* | 131.525 | Gamma | 30.553 | 4.305 | Mori et al., 2020 [27] |
| C-section performed by STP graduate  | 119.014 | - |  |  | estimated based on 11.5% of caesarean cost attributed to labour (Mori et al., 2020) & STP graduates paid 17.2% of consultant surgeons (Salaries from Sierra Leone Ministry of Health & Sanitation) [27] |
| Normal delivery [*α, θ]* | 22.525 | Gamma | 9.99 | 2.255 | Mori et al., 2020 [27] |
| ***Maternal outcomes model parameters*** |
| Probabilities - Maternal outcomes |
| No complications| planned c-section | 0.907 | - |  |  | 1-p(complications)-(death) |
| Complications | planned c-section [**α,** β] | 0.09 | Beta | 153 | 1552 | CapaCare logbook data |
| Maternal death | planned c-section [**α,** β] | 0.004 | Beta | 6 | 1705 | CapaCare logbook data |
| No complications| emergency c-section | 0.871 | - |  |  | 1-p(complications)-(death) |
| Complications | emergency c-section [**α,** β] | 0.117 | Beta | 1897 | 14275 | Logbook data |
| Maternal death | emergency c-section [**α,** β] | 0.011 | Beta | 13 | 1133 | Duinen et al., 2021 [24] |
| No complications| emergency c-section not available | 0 | Fixed |  |  | 1-p(complications)-(death); assumed |
| Complications | emergency c-section not available | 0.803 | - | NA | NA | 1-p(death if caesarean not available); assumed  |
| Maternal death | emergency c-section not available | 0.197 | - | NA | NA | estimated as odds ratio (17.87) calculated from Carter & Walker 2022 \* p(death | emergency caesarean) [28] |
| Maternal costs |
| Complications (haemorrhage) [*α, θ]* | 93.175 | Gamma | 4.624 | 20.152 | Mori et al 2020, mean of reported provider perspective costs, 2018 [27] |
| DALYs - Disability weights: Maternal outcomes model |
| *Antepartum complications (applied when emergency c-section required)* |  |  |  |  |  |
| Obstructed labour [lower bound, upper bound] | 0.11 | Uniform | 0.05 | 0.15 | Roberts et al., 2016 [29] |
| Antepartum haemorrhage [lower bound, upper bound] | 0.5 | Uniform | 0.4 | 0.6 | Roberts et al., 2016 [29] |
| Hypertensive disease/ Eclampsia [lower bound, upper bound] | 0.5 | Uniform | 0.4 | 0.6 | Roberts et al., 2016 [29] |
| Malpresentation/ transverse lie [lower bound, upper bound] | 0.05 | Uniform | 0.01 | 0.1 | Roberts et al., 2016 [29] |
| *Postpartum complications* |  |  |  |  |  |
| Abdominal pain [lower bound, upper bound] | 0.114 | Uniform | 0.078 | 0.159 | Global Burden of Disease, 2019 [30] |
| Maternal haemorrhage (<1l blood lost) [lower bound, upper bound] | 0.114 | Uniform | 0.078 | 0.159 | Global Burden of Disease, 2019 [30] |
| Maternal infection [lower bound, upper bound] | 0.051 | Uniform | 0.032 | 0.074 | Global Burden of Disease, 2019 [30] |
| Duration of disability (days) |
| Abdominal pain from surgery, no complications [Mean, SD] | 7 | Normal | 7 | 1.75 | Expert clinical opinion |
| All antepartum complications  | 365 | Fixed | 0 | 0 | Assumed based on Roberts et al 2016 [29] |
| Haemorrhage [Mean, SD] | 7 | Normal | 7 | 1.75 | Expert clinical opinion |
| Infection [Mean, SD] | 18 | Normal | 18 | 4.5 | Expert clinical opinion |
| Persistent abdominal pain [Mean, SD] | 150 | Normal | 150 | 37.5 | Expert clinical opinion |
| ***Child outcomes model parameters*** |
| Probabilities - Child outcomes |
| No complications| planned c-section | 0.896 | - |  |  | 1-p(complications)-(death) |
| Complications | planned c-section [**α,** β] | 0.026 | - |  |  | Mazimpaka et al, 2020 & Duinen 2020; estimated as probability complications| emergency c-section) \* odds ratio 0.25 from Duinen et al 2020 [26, 31] |
| Child death | planned c-section [**α,** β] | 0.078 | Beta | 13 | 153 | Duinen et al., 2020 [26]  |
| No complications| emergency c-section | 0.746 | - |  |  | 1-p(complications)-(death) |
| Complications | emergency c-section [**α,** β] | 0.103 | Beta | 59 | 513 | Mazimpaka et al., 2020 [31] |
| Child death | emergency c-section [**α,** β] | 0.151 | Beta | 208 | 1168 | Duinen et al., 2019 [32]  |
| No complications| emergency c-section not available | 0 | Fixed |  |  | 1-p(complications)-(death); assumed |
| Complications | emergency c-section not available | 0.56 | - |  |  | 1-p(death if caesarean not available); assumed  |
| Child death | emergency c-section not available | 0.44 | - |  |  | estimated as odds ratio (2.91) calculated from Carter & Walker 2022 \* p(death | emergency caesarean) [28] |
| Child costs (USD) |
| Complications following C-section [*α, θ]* | 124.0 | Gamma | 16 | 7.750 | Ngabonzima et al, 2022, reported 2021 cost adjusted to 2018 value [33] |
| Complications following normal delivery [*α, θ]* | 173.3 | Gamma | 16 | 10.831 | Ngabonzima et al, 2022, reported 2021 cost adjusted to 2018 value [33] |
| DALYs - Disability weights: Child outcomes model |
| *Antepartum complications (applied when emergency c-section required)* |  |  |  |  |  |
| Obstructed labour [lower bound, upper bound] | 1 | Uniform | 0.9 | 1 | Roberts et al., 2016 [29] |
| Antepartum haemorrhage [lower bound, upper bound] | 0.119 | Uniform | 0.05 | 0.15 | Roberts et al., 2016 [29] |
| Malpresentation/ transverse lie [lower bound, upper bound] | 1 | Uniform | 0.9 | 1 | Roberts et al., 2016 [29] |
| Hypertensive disease/ Eclampsia [lower bound, upper bound] | 0.5 | Uniform | 0.4 | 0.6 | Roberts et al., 2016 [29] |
| Foetal distress [lower bound, upper bound] | 0.5 | Uniform | 0.4 | 0.6 | Roberts et al., 2016 [29] |
| *Postpartum complications* |  |  |  |  |  |
| Prematurity [lower bound, upper bound] | 0.061 | Uniform | 0.04 | 0.089 | Global Burden of Disease, 2019 [30] |
| Birth asphyxia [lower bound, upper bound] | 0.236 | Uniform | 0.165 | 0.323 | Global Burden of Disease, 2019 [30] |
| Neonatal infection [lower bound, upper bound] | 0.402 | Uniform | 0.268 | 0.545 | Global Burden of Disease, 2019 [30] |
| Duration of disability (days) |
| All antepartum complications | 365 | Fixed |  |  | Assumed based on Roberts et al., 2016 [29] |
| Prematurity [*α, θ]* | 15 | Gamma | 1.235 | 12.15 | Ngabonzima et al., 2022 [33] |
| Birth asphyxia [*α, θ]* | 15 | Gamma | 1.235 | 12.15 | Ngabonzima et al., 2022 [33] |
| Neonatal infection [*α, θ]* | 15 | Gamma | 1.235 | 12.15 | Ngabonzima et al., 2022 [33] |
| \* Parameter 1 and 2 labels according to the distribution being described are provided in square brackets after the parameter name.1 A lower bound=12 and upper bound=60 for age was applied to ensure plausible values.2 Planned C-sections are assumed to be available and received under the assumption that they would not be planned if not available.Note: STP= Surgical Training Programme; USD= United States Dollars; DALYs= Disability Adjusted Life Years; SD= Standard Deviation; C-section= Caesarean section |

As much as possible, parameters representing the context and situation specific to Sierra Leone were used within the analysis. In Sierra Leone there are limited systematic records of health system activity. Consequently, data collected by CapaCare as part of their organisational monitoring proved a valuable resource. CapaCare’s annual accounts provided information on the resources and costs associated with running the STP, as well as the continued support and supervision that is provided to STP graduates [34]. In addition, as part of the quality monitoring of STP graduates, all students and graduates are asked to maintain a surgical logbook detailing all surgeries performed along with some outcomes. In addition, because of the links with the STP graduates and the Ministry of Health and Sanitation (MOHS) in Sierra Leone, it was also possible to obtain some information on salaries within the healthcare system. These data sources were used along with data from the Sierra Leone Demographic and Health Surveys (SLDHS) which track maternal and child health indicators across the country [35]. In cases where data could not be obtained from these sources, or where the robustness of the data came into question, these data sources were supplemented with data from the literature.

#### 2.3.1 The patient cohort

The patient cohort, representing the cohort of women needing C-section in Sierra Leone, was estimated for the year 2012 based on the expected births in that year and the estimated indication for C-section. The year 2012 was used representing the year before the STP had produced any graduates. Although a number of variables in the estimation of need for C-section have changed over time, of particular note being the population size, in order to isolate the effect of the STP this value was held constant in the analysis representing a world where the population remained constant and consequently so does the expected need for C-section. As such, we assume that the annual need for C-section remains constant between 2012 and 2018 (the period for which consistent logbook data is available) to facilitate a modelled analysis of the impact of the STP on access to surgery and subsequent outcomes. 2018 is the analysis year because, while the STP continues to run to the present day, after 2018 some changes to the STP were implemented, including increasing the number of medical doctors and other cadres of healthcare professional taking the course, changing the way surgeries are recorded in logbooks, and alterations to MOHS participation and monitoring. In addition, COVID-19 impacted the data collected in subsequent years. Consequently, data from 2012 to 2018 was used as it reflected a period where surgical task-shifting was implemented in a consistent way and without the impact of COVID-19.

#### 2.3.2 Availability of C-section in Sierra Leone

Parameters to estimate the availability of C-section in Sierra Leone were informed by the estimated patient cohort and data on C-sections performed in 2012 from a retrospective country wide survey [36]. The availability of C-section with the STP was estimated based on the estimated additional surgeries provided by STP graduates, informed by data from surgical logbooks and CapaCare records and validated with reference to a country wide survey in 2012, estimates of surgical productivity among STP graduates and the contribution of the STPs to the surgical workforce [12, 36, 37]. These estimates assume that the graduate’s productivity levels, and the proportion of surgeries performed that are C-sections, remain constant. The proportion of C-sections that were planned and emergency was informed by a study conducted in Sierra Leone on maternal costs and outcomes by Duinen et al. [24, 26]. We assume that the proportion of planned (0.145) vs emergency (0.855) C-sections remains the same with and without the STP. These proportions are applied to the availability of C-section (which increases with the STP) to determine the probability of receiving a planned or emergency C-section with and without the STP (see Table 1 for details of parameter calculations).

#### 2.3.3 Probability of complications and death

The probability of complications and death following planned and emergency C-section was informed by data from CapaCare surgical logbooks and values from published literature [24, 26, 38]. This analysis assumes that outcomes for each type of surgery do not differ depending on whether the surgery is performed by a medically trained surgeon or an STP graduate. This is informed by a study to evaluate the quality of surgery provided by the STP graduates in Sierra Leone which found that the surgical care provided was non-inferior to that provided by medically trained surgeons [12, 15]. In fact, the study found that on some indicators, outcomes were better for surgeries performed by STP graduates. However, as some differences in quality of care and subsequent patient outcomes have been observed where surgical task-shifting has been employed in other countries, the extent to which any differences in outcomes would impact the cost-effectiveness result was explored in a threshold analysis. This aimed to identify the maximum difference in the rate of complications and death with STP graduate ACs compared with medically trained surgeons and for the programme to be considered cost-effective.

Data on what happens to women if they need a C-section but are unable to access one is not available in the current literature. It is anticipated that in this situation outcomes are very poor with high chance of mortality and complications. However, identifying any data on this proved extremely challenging. Consequently, it was assumed that all women who needed a C-section but weren’t able to access one, suffered complications. The probability of death if a C-section was needed but not available was estimated based on a study by Carter and Walker which analysed maternal and child outcome data across countries [28]. Data from this study was used to calculate odds ratios for maternal, and child, mortality with no coverage relative to full coverage which was applied to the probability of death when emergency C-section was available to estimate the probability of death when C-section was not available.

### 2.4 Outcomes

The primary outcome for the cost-effectiveness analysis was disability adjusted life years (DALYs). DALYs were calculated as the sum of years of life lost (YLL) due to premature death and the years lived with disability (YLD) as a result of childbirth and any complications:

$$DALY=YLL+YLD$$

YLL is calculated as:

$$YLL=N\*L$$

Where N is the number of deaths, and L is the remaining life expectancy based on WHO standard life-expectancy for calculation of YLL, in years, at the age of death [39].

YLD is calculated as:

$$YLD=\left(I\*D\right)\*W$$

Where I is the number of incident cases, D is the duration of disability, and W is the disability weight associated with the condition.

DALYs were calculated using the life expectancy standard loss function, relevant disability weights which were applied based on the expected patient symptoms and outcomes for each patient pathway (e.g. with/ without complications) and estimates of duration of patient symptoms following surgery informed from clinical input and the literature. Relevant disability weights and parameters for duration of symptoms used to calculate DALYs are presented in Table 1. Based on available evidence, which was limited to the time at the facility and some short term follow up, and in-line with previous studies, disability weights associated with complications were applied in the YLD calculation for up to 1 year in the base case. However, as the impact of some complications may be experienced for a longer period [15], this was explored in sensitivity analysis. A discount rate of 3% was applied YLDs accrued beyond 1 year (in sensitivity analysis) and YLLs due to premature death, based on recommendations of the iDSI reference case for health economic evaluations [40]. No age-weighting was used in the calculation of DALYs.

### 2.5 Costs

All costs used in the analysis are presented in Table 1. Any costs initially estimated in other currencies were converted to 2018 USD based on relevant exchange rates obtained from [www.exchangerates.org.uk](http://www.exchangerates.org.uk) and inflation rates obtained from www.macrotrends.net to ensure consistent currency-price year units [41, 42]. In the base case 2018 was used as the analysis year reflecting the end of the period with consistent data (explained above). However, we also conducted a sensitivity analysis converting costs to 2024 USD.

#### 2.5.1 Procedure costs

There is limited cost data from a healthcare provider perspective available in Sierra Leone. Some data on healthcare provider salaries were obtained from the MOHS, however there was not sufficient data on all aspects of care required for childbirth to generate robust estimates. Consequently, cost estimates were based on data from a recent systematic review of surgery costs in sub-Saharan Africa [27]. The cost estimates from the systematic review were then scaled down to estimate a cost for C-sections performed by STP graduate ACs reflecting the lower salaries they are paid compared with medically trained surgeons. Referring back to original studies in the systematic review, an estimated 11.5% of the total cost for C-section was made up by the labour cost, so using information from the MOHS in Sierra Leone on the difference in salaries for different healthcare professionals this value was scaled down to reflect the lower salaries of STP graduate ACs.

#### 2.5.2 STP costs

A cost associated with the STP attributable to each surgery was also estimated. This was based on data from CapaCare annual accounts on the costs to run the STP (Mean (SD) annual cost: USD 425,350 (73,969)), the number of STP graduates trained (mean (SD)= 7.4 (2.3)), the number of surgeries graduates perform each year, the proportion of all surgeries that were C-sections and an estimated number of years that graduates would be clinically active in Sierra Leone for. As there is known to be underreporting of surgeries performed by STP graduates in surgical logbooks (it is estimated that only 39% of surgeries are recorded), the number of C-sections performed was scaled in this calculation to reflect the estimated under-reporting [43]. The level of underreporting was informed by a recent study in Sierra Leone of surgical activity [44]. Values for surgeries reportedly completed by STP graduates in this study were compared with the logbook records to estimate the under-reporting. It is anticipated that even in the recent surgical activity study there could still be under-reporting, but this represented the best estimate available at the time of the analysis. Additional details are provided in Supplementary Appendix 1.

### 2.6 Cost-effectiveness analysis

The primary analysis explored the cost-effectiveness of C-section provision with the STP compared with C-section provision without the STP in Sierra Leone. A lifetime horizon was considered to capture the mortality and morbidity resulting from complications as DALY pay offs in the model. However, as only data from the procedure and limited follow up data was available, data on long term effects of complications was limited. As such, in the base case analysis disability weights associated with complications were applied for 1 year, in line with previous studies, but the impact of this was explored in sensitivity analysis applying the disability weight associated with relevant complications for the remaining life expectancy. The analysis was undertaken from the healthcare system perspective as in Sierra Leone maternal and child healthcare is provided free of charge and consequently the cost of providing this care falls on the healthcare system. Inclusion of demand side costs borne by households, such as informal payments, transport and other opportunity costs like lost earnings were considered but were not included due to lack of data. Nevertheless, these demand side costs are expected to be lower with the STP (for example, due to there being more providers at more facilities across the country so travel costs to reach a facility where C-section is available are expected to be lower), and so their inclusion in the analysis would reinforce the result obtained without them. As such, the healthcare system perspective is the most policy relevant and feasible for this decision problem. In addition, long term sustainability of the STP may depend on its ability to be encompassed by the MOHS, who have had some involvement with the programme from its conception. As such the STP running costs, also represent costs that would be borne by the health system if this training programme was adopted by the MOHS.

Mean costs and DALYs were calculated for each of the scenarios and the incremental cost-effectiveness ratio (ICER) was estimated as:

$$ICER=\frac{Incremental cost}{DALYs averted}$$

Where, incremental cost is the expected cost associated with childbirth for women in need of C-section in Sierra Leone with the STP minus the expected cost associated with childbirth for women in need of C-section in Sierra Leone without the STP; and DALYs averted is the expected DALYs without the STP minus the expected DALYs with the STP. Cost-effectiveness results based on maternal costs and outcomes only are presented alongside cost-effectiveness results based on combined maternal and child costs and outcomes. This is to allow comparison with other C-section evaluations, many of which capture only maternal outcomes, and also because the data available for child outcomes is much more limited so there is greater uncertainty in that part of the analysis.

#### 2.6.1 Cost-effectiveness threshold

There is no pre-defined cost-effectiveness threshold for Sierra Leone. We therefore present cost-effectiveness results on the cost-effectiveness acceptability curve (CEAC). As an aid to decision making, we mark on the cost-effectiveness plane thresholds representing GDP per capita and 3 times GDP per capita, thresholds which though are no longer endorsed by WHO are commonly cited in the literature. Recent literature suggests that for low human development index countries, the cost-effectiveness threshold is likely to be lower than GDP per capita [45]. Consequently, a USD 12 per DALY averted threshold is also presented, representing the lowest supply side threshold value estimated by Ochalek et al [46]. Decision makers should compare the cost-effectiveness results with the threshold that is relevant to their decision-making context.

### 2.7 Sensitivity analyses

A series of scenario sensitivity analyses were undertaken to explore the main assumptions and uncertainties within the model and underlying data. Parameters used in the sensitivity analyses are presented in Supplementary Appendix 2 (base case values were used for any parameters not listed).

The main way that the STP affects provision of maternal and child healthcare is through increased availability of C-section. However, there are potential known biases with the data reported in the surgical logbooks and uncertainty around the extent to which the STP will increase access to surgery. Consequently, we undertook threshold analysis to explore the minimum increase in access to C-section that could be tolerated for the STP to be considered cost-effective. We also explored this using probabilistic one-way sensitivity analysis in which the number of C-sections performed by STP graduate ACs in addition to those provided by medically trained surgeons was varied between 0 and 10,000 to see the impact on the cost-effectiveness results [47]. To demonstrate the impact of the magnitude of increase in access we plotted the conditional incremental net monetary benefit for each value tested in the probabilistic one-way sensitivity analysis. Net monetary benefit is a transformation of the cost-effectiveness decision rule for ICERs which removes ambiguity in interpretation of results (e.g. negative ICERs) [48]. The decision rule that the ‘new treatment’ should be implemented if the ICER is less than the cost-effectiveness threshold can be re-arranged to calculate net monetary benefit as follows:

$$ICER: \frac{Incremental cost}{DALYs averted}<λ$$

$$NMB:λ x DALYs averted-Incremental cost>0 $$

Where, $λ$ is the cost-effectiveness threshold. Although there is no specified cost-effectiveness threshold for Sierra Leone, net monetary benefit requires the specification of a threshold and so a threshold value of USD 519.65 (GDP per capita 2018) is used for this analysis.

In the base case, the number of surgeries performed by STP graduate ACs was scaled for under-reporting in the calculation of the STP cost attributable to each surgery. A sensitivity analysis was undertaken using only the data from the logbooks (not accounting for under-reporting). Uncertainty around the cost of normal delivery which is applied in the case where C-section is not available was also explored. In our analysis the patient cohort are those who need a C-section and normal delivery only occurs when C-section is not available. It is therefore likely that some additional intervention to assist with delivery may be attempted. As such, the cost of normal delivery used in the base case is likely to underestimate the cost of delivery in this situation. Consequently, a scenario analysis in which the cost of normal delivery was increased to account for additional equipment and other resources that may be required in a more complex delivery. The increase was informed by a Canadian study which estimated costs associated with childbirth with varying levels of complexity [49]. Although the Canadian context is very different to Sierra Leone, in the absence of data from a more relevant context, this study served as a best estimate of the potential scale of difference in cost. An additional sensitivity analysis was undertaken in which costs were converted to 2024 USD (as compared with 2018 USD used in the base case), to explore the impact of using 2018 as the analysis year. This analysis implies an extension to assumptions used in the base case that population size, and consequently need for c-section, is held constant from 2012 to the analysis year - 2024 in this sensitivity analysis.

Uncertainty around the outcomes was also explored in sensitivity analyses. In the base-case analysis, disability weights for antepartum complications were informed by a study by Roberts et al [29]. However, in this study a simplified DALY calculation was used, and the duration of disability was not specified. Consequently, in the base case it was assumed that the disability weights had been scaled accordingly and so they were not further scaled, effectively applying them for 1 year. However, given the uncertainty, a sensitivity analysis was undertaken in which the disability weights associated with antepartum complications were applied for 30 days in the DALY calculation, in line with common quality measures which monitor surgical outcomes at 30 days. An alternative plausible scenario is that the effects of some complications are experienced for a longer time frame. For example, a recent study provides some evidence that the effects of chronic pain may be experienced by some women at 5 years follow up [15]. However, data on duration of disability for all complications included in the model is not available in this setting and even for chronic pain, duration beyond 5 years is not known. Consequently, the impact of this was explored using an ‘extreme value’ sensitivity analysis in which disability weights for complications were applied for the remaining life expectancy i.e. the maximum duration of disability is included in the DALYs. Additional sensitivity analyses were also undertaken using the highest and lowest available values for disability weights to explore the impact of the uncertainty in these values.

Probabilistic sensitivity analysis was also undertaken using Monte-Carlo simulations to evaluate the overall uncertainty in the model. Results were plotted on the cost-effectiveness plane showing the uncertainty around the point estimate of cost-effectiveness, and on the CEAC showing the probability of cost-effectiveness over a range of cost-effectiveness threshold values (CEAC in Supplementary Appendix 3).

Although evidence from Sierra Leone indicates no difference in outcomes from surgery depending on whether it is performed by a medically trained surgeon or an STP graduate AC, the issue of quality of care when surgical task-shifting has been employed has been contentious in other settings. Consequently, to explore this issue, an additional threshold analysis was also undertaken to explore the impact of any difference in complication rates between medically trained surgeons and surgery performed by STP graduate ACs on the cost-effectiveness result. This aimed to identify the maximum increase in rates of complications and death with surgery performed by STP graduate ACs compared to medically trained surgeons that could be tolerated for the programme to be considered cost-effective.

## 3. Results

### 3.1 Cost-effectiveness analysis

The primary cost-effectiveness analysis results are presented in Table 2.

Table 2: Base case cost-effectiveness results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Expected cost (USD)** | **Incremental cost (USD)** | **Expected DALYs** | **DALYs averted** | **ICER: cost per DALY averted** |
| *Maternal outcomes model* |   |   |   |   |
| **Without STP** | 125.91 |   | 3.75 |   |   |
| **With STP** | 129.94 | 4.03 | 2.97 | 0.78 | 5.18 |
| *Combined results* |   |   |   |   |   |
| **Without STP** | 245.16 |   | 14.48 |   |   |
| **With STP** | 228.39 | -16.77 | 12.34 | 2.14 | STP dominates |
| Note: STP= Surgical Training Programme; USD= United States Dollars; DALYs= Disability Adjusted Life Years; ICER= Incremental Cost-Effectiveness Ratio |

The CapaCare surgical training programme results in a large number of additional C-sections (estimated around 2017 additional C-sections per year based on current data available), and consequently, DALYs averted due to avoidance of maternal and child deaths as well as reduced severe complications. When considering only maternal outcomes, the cost per DALY averted as a result of the STP is USD 5.18. Compared with available cost-effectiveness threshold estimates for Sierra Leone, this indicates that increasing provision of C-section through the CapaCare STP is likely to be considered cost-effective. Furthermore, when child outcomes (and associated costs) are also included in the analysis, lower total healthcare costs and better overall health outcomes indicate surgical provision of C-section with the STP dominates (lower cost, better outcomes) that which is provided without the STP.

Results of the probabilistic sensitivity analysis are presented on the cost-effectiveness plane in Figure 2. The cloud of point estimates lies entirely to the right of the y-axis indicating certainty that provision of surgery as a result of the STP improves maternal and child outcomes. As the cloud of point estimates straddles the x-axis, this illustrates there is some uncertainty around the costs. However, as the magnitude of the spread above and below the x-axis is relatively small, this indicates the difference in costs is likely to be small. Consequently, at cost-effectiveness thresholds of USD 519, USD 1558, and USD 12 per DALY averted, all of the points lie below the line, indicating a 100% probability that the STP is a cost-effective way to increase provision of C-section in Sierra Leone at these thresholds. The cost-effectiveness plane with maternal outcomes only is available in Supplementary Appendix 4.



Figure 2: Cost-effectiveness plane - combined maternal and child analysis

### 3.2 Sensitivity analyses

The results of the sensitivity analyses are presented in Table 3. The results of the main analysis were robust to all sensitivity analyses explored. This indicates that increasing provision of C-section through the CapaCare STP would be considered cost-effective in Sierra Leone.

Threshold analysis to explore the minimum increase in access to C-section that could be tolerated for the STP to be considered cost-effective indicated that a minimum of 85 C-sections in addition to those already provided by medically trained surgeons would need to be performed by STP graduate ACs each year. This equates to a minimum of 1.73 percentage point increase in access being required for the provision of C-section with the STP to be considered cost-effective. Given that even the conservative estimates of the number of C-sections performed by STP graduate ACs each year since the programme began are well above this figure, this emphasises the result that provision of C-section with the STP would be considered cost-effective in Sierra Leone. The line graph of the probabilistic one-way sensitivity analysis results is presented in Figure 3 which provides additional detail on the impact on cost-effectiveness when the access to C-section increases. An extended version of this plot showing the results of the analysis for a larger range of additional C-sections provided is provided in Supplementary Appendix 5.

Threshold analysis on the difference in rates of complications and death between STP graduate ACs and medically trained surgeons, indicated that rates of complications and death could be up to 4.5 times higher with STP graduate ACs and maintain a result indicating that the STP is a cost-effective option for increasing provision of C-section in Sierra Leone. This means, that provided rates of complications and death are not more than 4.5 times higher than with medically trained surgeons, surgical task shifting could be considered a cost-effective option in Sierra Leone. However, this assumes that the care provider is risk neutral, and in reality, a 4.5 time increase in complications and death is not likely to be acceptable.

Table 3: Sensitivity analyses results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Expected cost (USD)** | **Incremental cost (USD)** | **Expected DALYs** | **DALYs averted** | **ICER: cost per DALY averted** | **Incremental net benefit (USD)1** |

|  |
| --- |
| **Base case analysis** |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Without STP | 245.16 |  | 14.48 |  |  |  |
| With STP | 228.39 | -16.77 | 12.34 | 2.14 | STP dominates | 1128.76 |
| **Sensitivity analyses** |
| *STP costs based on data from logbooks only* |
| Without STP | 245.16 |   | 14.48 |   |   |   |
| With STP | 242.89 | -2.27 | 13.63 | 0.85 | STP dominates | 441.78 |
| *Normal delivery cost scaled to account for additional interventions* |
| Without STP | 249.18 |   | 14.48 |   |   |   |
| With STP | 231.48 | -17.69 | 12.34 | 2.14 | STP dominates | 1129.68 |
| *Duration of antepartum complications scaled to 30 days* |
| Without STP | 245.16 |   | 14.40 |   |   |   |
| With STP | 228.39 | -16.77 | 12.26 | 2.14 | STP dominates | 1127.72 |
| *High values for disability weights* |
| Without STP | 245.16 |   | 14.55 |   |   |   |
| With STP | 228.39 | -16.77 | 12.40 | 2.15 | STP dominates | 1132.79 |
| *Low values for disability weights* |
| Without STP | 245.16 |   | 14.39 |   |   |   |
| With STP | 228.39 | -16.77 | 12.25 | 2.14 | STP dominates | 1126.94 |
| *Disability weights associated with complications applied for remaining life expectancy* |
| Without STP | 245.16 |  | 47.224 |  |  |  |
| With STP | 228.39 | -16.77 | 41.783 | 5.441 | STP dominates | 2844.2 |
| *Costs converted to 2024 USD* |
| Without STP | 431.93 |  | 14.48 |  |  |  |
| With STP | 400.3 | -31.62 | 12.34 | 2.14 | STP dominates | 1143.61 |
| 1 Incremental net benefit calculated using cost-effectiveness threshold value=USD 519.65 (GDP per capita 2018) in the absence of an agreed threshold value. This is to illustrate the relative impact of each sensitivity analyses but does not indicate that this is the considered the correct threshold for Sierra Leone.Note: STP=Surgical Training Programme; USD= United States Dollars; DALYs= Disability Adjusted Life Years; ICER+ Incremental Cost-Effectiveness Ratio |

Figure 3 Line graph probabilistic one-way sensitivity analysis around increased access to C-section

## 4. Discussion

### 4.1 Key findings

There is limited access to surgical care across Sierra Leone due to lack of surgical workforce and concentration of surgical expertise in the capital city; and this puts the health of women in need of C-section at increased risk of mortality and morbidity. Our analysis shows that increased access to C-section provided by STP graduate ACs who are not medical doctors, but who have been trained in the necessary surgical skills, is cost-effective compared to C-section provision without the STP. This conclusion was maintained with all the sensitivity analyses explored. Furthermore, the benefits of the STP could be underestimated if the level of under-reporting of surgeries in the logbooks is even greater than has been accounted for.

To date, the STP is estimated to have cost USD 425,350 per year to run on average. This represents 0.1% of the total reported health expenditure in Sierra Leone in 2019 [50]. Furthermore, when treatment cost impacts are taken into account, provision of care for mothers in need of C-section and their babies with the STP results in a cost saving of USD 16.77 per patient. Scaling this up by the estimated need for C-section in Sierra Leone, indicates implementing the STP would result in a healthcare budget saving of USD 1,039,069 over 5 years. This assumes that need for C-section would remain constant, however if the number of C-sections needed increases (e.g., with increasing population), then the cost saving would be even higher. However, if scaling up the STP, a number of considerations would also need to be taken into account. One consideration is that the input for the programme (the students taking the course) are primarily CHOs and PAs, and the pool of CHOs and PAs is limited. Consequently, replacement of CHOs and PAs undertaking the STP should be accounted for, particularly as they are also employed to provide care elsewhere in the healthcare system, meaning that them joining the STP will create a care provision gap elsewhere. Furthermore, while the STP graduates increase the surgical workforce, a balance should be maintained between the number of surgically trained CHOs/PAs and medically trained surgeons and so increases in the number of medically trained surgeons would also be required over time. It was beyond the scope of this study to include training costs for MDs and CHOs/PAs but given that 6-year MD training is much more costly than 3-year CHO training, it may have resulted in even higher cost-effectiveness in the task-shifting group. Future research should explore these considerations if the STP is to be scaled up in Sierra Leone or elsewhere.

### 4.2 Strengths and limitations

A key strength of this analysis is the use of real world, country specific data to inform model parameters. CapaCare training programme records and accounting information along with surgical logbook data from trainees and graduates proved valuable resources and allowed us to undertake a country-specific evaluation in what would otherwise be a data-limited environment. Although the logbook data has its own limitations, because of the efforts of the CapaCare team to understand those limitations, we were able to account for them in the analysis; for example, by adjusting the number of surgeries for known under-reporting using data from a recent national study [44]. In addition, the inclusion of child costs and outcomes as a result of increased access to C-section is a further strength of this analysis as often analyses are limited to maternal outcomes only which can mean true costs and outcomes of alternatives being evaluated are not estimated accurately.

This analysis evaluates surgical task-shifting for C-section implemented through the CapaCare STP which aims to address one of the key barriers to surgery in Sierra Leone: availability of surgical providers [20]. However, access to surgery, and in particular C-section, is a multi-faceted problem and other barriers should also be considered in policies to increase access to C-section including availability of theatres and referral systems [19]. While availability of theatres is addressed to some extent by the STP in collaboration with MOHS when graduates are ‘posted’ to facilities, the referrals system is not explicitly addressed in this study.

A number of assumptions were required to facilitate the analysis which aims to evaluate the impact of the STP on provision of /access to C-section in Sierra Leone and subsequent outcomes for mothers and babies. One of the nuances of this analysis is that it is consequently not possible to have data with the STP and without the STP at the same time. We therefore draw on data from 2012 (before the STP produced graduates) and since the STP started (up to 2018) to construct a modelled analysis of the impact of the STP on access to surgery and subsequent outcomes. To facilitate this analysis certain assumptions are required such as holding the population size and need for C-section constant at 2012 levels over the analysis period. Although this assumption was required, it represents a limitation as in reality the population was increasing and so need for C-section was also likely increasing.

In addition, this analysis uses data on planned and emergency C-sections in Sierra Leone, however it was not possible to determine whether planned C-sections were elective. Consequently, it is possible that some of the C-sections recorded in the data were elective and so would not be defined as clinically necessary. For example, some women, if they had the resources to do so, may have chosen a C-section rather than normal delivery for reasons other than clinical need, such as personal preference. This represents a limitation in our analysis as we start from the position of a C-section being needed and in the case that women opt for elective C-section this condition is not strictly met. However, in Sierra Leone, rates of C-section remain below 5% in all but the highest wealth quintile and all but two districts according to DHS [35]. Given that a C-section rate of 10-15% is usually considered optimal, this suggests that there are unlikely to be many elective-, not clinically necessary, C-sections in this setting.

Another assumption within our analysis is that the complication rate for STP graduate ACs and medically trained surgeons is the same. This is based on a study to evaluate the quality of surgery provided by the STP graduate ACs which found that the surgical care provided was non-inferior to that provided by medically trained surgeons [12, 14]. In fact, the study found that on some indicators, outcomes were better for surgeries performed by STP graduates. Furthermore, STP graduates are not limited to only performing C-section but provide a range of surgical procedures and emergency obstetric care. A study has also been conducted exploring quality of care among STP graduates providing inguinal hernia, and this also showed non-inferiority (or even superiority) for those performed by STP graduates [51]. This may be counter intuitive considering lower levels of medical training. However, there are many factors which could influence this. For example, in the Sierra Leonean setting many MDs, despite higher levels of medical training, actually have low levels of surgical experience because of the lack of supportive supervision for surgical procedures across the country. Another argument is that perhaps outcomes may be worse for surgeries performed by medically trained surgeons if they take more severe cases. Consequently, we used the available evidence of non-inferiority to inform our analysis, but if outcomes are actually better for surgeries performed by STP graduates this would mean that our analysis further underestimates the benefits associated with the STP. We also conducted threshold analysis which indicated that complication rates could be up to 4.5 times higher with STP graduates and still be cost-effective. This is not to say that complication rates 4.5 times higher is expected, nor that this would be considered acceptable, but it provides a threshold limit that could be used to put future monitoring of patient outcomes into context.

### 4.3 Methodological challenges

#### 4.3.1 Data limitations

A number of data limitations posed methodological challenges in this analysis. This is partly due to the setting, as Sierra Leone has limited health data infrastructure and so many of the data items needed for the analysis were difficult to identify. While every effort was made to identify model parameters that were specific to the Sierra Leonean context, the limited data meant that in some cases data based on other settings had to be used in the analysis.

One particular challenge specifically related to the clinical setting is that no data could be identified on what happens to mothers and babies if there is a need for C-section but there is no suitable healthcare provision available to provide it. There are good reasons for why this data is never reported. One is that it could present ethical questions in research settings if data is collected in real time about the consequences without intervening to improve outcomes. In addition, it could be ethically sensitive for healthcare professionals to disclose events that may not have strictly adhered to clinical guidelines and led to poor outcomes. Another is that although maternal and child deaths are recorded in some routine data particularly linked to monitoring progress towards global goals, this is often limited to count data and the reasons for death are not often recorded in this setting. Furthermore, there is often no comprehensive health management information system which makes tracking patients extremely difficult, and, in many cases, trained birth attendants who might record such data may not be present. Even where reason for death may be recorded it would likely be listed as birthing complications and it is difficult to disentangle those who could have been saved if a C-section had been available.

A further data challenge was in relation to child outcomes following C-section because in this setting, child outcomes are not well reported. The majority of Sierra Leonean studies focus on maternal outcomes only, and those that do include child outcomes tend to report mortality only. Furthermore, only data on relatively short-term outcomes were available, usually limited to the hospital period or in a few studies including one follow up a few months later. This is likely in part due to the difficulty in following up mothers and babies to link longer term outcomes to circumstances at birth.

#### 4.3.2 Evaluating an access improving intervention

The main benefit of the surgical task-shifting is increased access to surgical care, rather than a change in the surgical method or other care provided. By applying standard methods of economic evaluation, we have captured the impact of the increased access on average healthcare costs and outcomes only. We have not explicitly captured the magnitude of the increase in access, nor the equity of access, i.e., whose access to surgical care is increasing as a result of the surgical task-shifting and is it equitable? One factor that impacts access is cost, and particularly patient cost [52]. Current data on patient costs and catastrophic expenditure following C-section in Sierra Leone indicates that patients in the poorest quintile spend significantly more than patients in the richest quintile, with travel and food being the largest expenses, and that 12% of women encountered catastrophic expenditure (based on 10% threshold) despite maternal and child healthcare being free in Sierra Leone [24]. This indicates that to fully evaluate the equity of access, analyses should be stratified by wealth quintile and/or geography. This should be a focus of future research in this area.

In demonstrating that with standard methods of economic evaluation neither the magnitude of the increase in access, nor the equity of access, is captured, we highlight a further methodological challenge. If we are only aiming to identify the options that maximise population health, then the methods used in this analysis are sufficient. However, if one of the objectives is ensuring equitable access to healthcare (e.g. universal health coverage), then the standard methods of economic evaluation used in this analysis do not go far enough, as they do not explicitly measure and evaluate the changes in access to healthcare. If understanding access to healthcare is important to decision makers, then consideration should be given to the extent to which access to care has changed and for whom. Further research is needed in this area to support such analyses and ensure evaluations conducted meet the needs of healthcare decision makers who may be considering these health system objectives.

### 4.4 Implications of the results and recommendations or future research policy and practice

This study shows that surgical task-shifting, implemented through the CapaCare STP, is a cost-effective way to improve health outcomes associated with conditions treatable by surgery, namely maternal and child outcomes through increased provision of C-section. As such, it provides evidence in favour of surgical task-shifting in resource limited settings. Consequently, investment in surgical task-shifting initiatives should be considered by health policy and decision makers as a potentially cost-effective way to increase surgical provision where there are low rates of C-section coverage.

One key feature of the STP is that STP graduates are posted to healthcare facilities across the country. This is critical as previously, most surgical expertise was concentrated in the capital city, Freetown, meaning that much of the country’s population had little or no access to surgery. Universal health coverage is one of the key global development goals of the 2030 agenda and calls for fair access to healthcare for all who need it without risk of financial hardship. It is likely that the STP has also improved equitable access to surgery, but these benefits are not captured by standard methods of cost-effectiveness analysis. Despite this, standard methods of economic evaluation are still consistently used to inform healthcare reimbursement decisions even though they do not provide evidence on progress towards equitable access to healthcare.

Adaptations to current methods, or additional analyses to demonstrate the impact of proposed interventions on equity of healthcare access could provide vastly improved evidence to inform progress towards universal health coverage. For example, methods of equity informative cost-effectiveness analysis, such as distributional cost-effectiveness analysis or extended cost-effectiveness analysis, could be useful here [53-55]. However, these methods still focus on capturing the distributional impact on overall health (and costs) rather than changes in access per se. and can be difficult to implement in low resource settings due to the additional data requirements. It is likely that the appropriate methods would vary depending on the mechanism by which the intervention affected access. For example, in this case, the STP improves access to surgery geographically across the country and this has potential equity implications because of the profile of the population in different areas. Consequently, geospatial analysis of improvements in access to surgery as a result of the STP could provide useful additional information alongside the cost-effectiveness, on the benefits of the STP in terms of progress towards universal health coverage. Alternatively, more advanced modelling approaches could be explored to explicitly capture these effects within the economic evaluation; for example, using patient level simulation and incorporating parameters linked to patient characteristics to determine access and other outcomes. Future research should explore possible methods to provide evidence on progress towards universal health coverage alongside cost-effectiveness evidence, and how these methods vary depending on the mechanisms by which access to healthcare is affected by interventions being evaluated.

## 5. Conclusion

This study shows that surgical task-shifting, implemented through the CapaCare STP, is a cost-effective way to improve maternal and child health outcomes when there is an indication for C-section. As such, it provides evidence in favour of surgical task-shifting in resource limited settings. The STP has also likely improved equitable access to surgery, but these benefits are not captured by standard methods of cost-effectiveness analysis. Consequently, investment in surgical task-shifting initiatives should be considered by health policy and decision makers as a potentially cost-effective way to increase access to quality surgical services. However, current methods of economic evaluation do not routinely provide evidence on healthcare access or equity benefits and so evidence to inform such investment is often limited. Evaluations of access increasing interventions should seek to capture the distributional impact and system benefits besides demonstrating average cost-effectiveness.

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