BMJ Global Health

The rate and perioperative mortality of caesarean section in Sierra Leone

Hampus Holmer,[1,2,3] Michael M Kamara,[4] Håkon Angell Bolkan,[5,6] Alex van Duinen,[5,6] Sulaiman Conteh,[7] Fatu Forna,[8] Binyam Hailu,[8] Stefan R Hansson,[9] Alimamy P Koroma,[10] Michael M Koroma,[11] Jerker Liljestrand,[1] Herman Lonnee,[12] Santigie Sesay,[7] Lars Hagander[1,13]

To cite: Holmer H, Kamara MM, Bolkan HA, *et al*. The rate and perioperative mortality of caesarean section in Sierra Leone. *BMJ Global Health* 2019;**4**:e001605. doi:10.1136/bmjgh-2019-001605

Handling editor Sanni Yaya

► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/bmjgh-2019-001605).

Preliminary findings of this research were presented at the 9th Annual Sierra Leone Health and Biomedical Research Group (HBIOMED) conference in Freetown, Sierra Leone, on 17–19 October 2018.

Received 1 April 2019
Revised 22 July 2019
Accepted 3 August 2019

For numbered affiliations see end of article.

Correspondence to
Dr Hampus Holmer;
hampus.holmer@med.lu.se

ABSTRACT

Introduction Sierra Leone has the world's highest maternal mortality, partly due to low access to caesarean section. Limited data are available to guide improvement. In this study, we aimed to analyse the rate and mortality of caesarean sections in the country.

Methods We conducted a retrospective study of all caesarean sections and all reported in-facility maternal deaths in Sierra Leone in 2016. All facilities performing caesarean sections were visited. Data on in-facility maternal deaths were retrieved from the Maternal Death Surveillance and Response database. Caesarean section mortality was defined as in-facility perioperative mortality.

Results In 2016, there were 7357 caesarean sections in Sierra Leone. This yields a population rate of 2.9% of all live births, a 35% increase from 2012, with district rates ranging from 0.4% to 5.2%. The most common indications for surgery were obstructed labour (42%), hypertensive disorders (25%) and haemorrhage (22%). Ninety-nine deaths occurred during or after caesarean section, and the in-facility perioperative caesarean section mortality rate was 1.5% (median 0.7%, IQR 0–2.2). Haemorrhage was the leading cause of death (73%), and of those who died during or after surgery, 80% had general anaesthesia, 75% received blood transfusion and 22% had a uterine rupture diagnosed.

Conclusions The caesarean section rate has increased rapidly in Sierra Leone, but the distribution remains uneven. Caesarean section mortality is high, but there is wide variation. More access to caesarean sections for maternal and neonatal complications is needed in underserved areas, and expansion should be coupled with efforts to limit late presentation, to offer assisted vaginal delivery when indicated and to ensure optimal perioperative care.

Key questions

What is already known?

- Sierra Leone has the world's highest maternal mortality ratio, among the highest rates of stillbirth and neonatal death, and among the lowest caesarean section rates; yet prior to this study, no nationally representative data on the mortality of caesarean section had been published, and the most recent published data on the national caesarean section rate were from 2012, before the Ebola outbreak.

What are the new findings?

- The caesarean section rate in Sierra Leone has increased faster than the global average, and there is an unequal distribution across districts.
- The national caesarean section mortality rate is 1.5%; the most common cause of death is haemorrhage and uterine rupture was seen in over one in five of those who died.

What do the new findings imply?

- Overall, more access to caesarean sections for maternal and fetal indication is needed, particularly in underserved districts.
- Findings suggest that increasing the rate of caesarean section should be done in concert with efforts to strengthen emergency obstetric care in general—to limit late presentation, ensure there is capacity to perform instrumental delivery and improve perioperative care.

INTRODUCTION

Over a quarter-million maternal deaths and over 2 million stillbirths occur each year due to complications of pregnancy and childbirth,[1] but most of these deaths could be averted with timely emergency obstetric care, including caesarean section.[2] The WHO has recommended a caesarean section rate of at least 10% of live births and sometimes higher, depending on the local context.[3–5] Worldwide, almost 30 million caesarean sections are carried out annually.[6] Sierra Leone, a low-income country in West Africa, has the world's highest estimated maternal mortality ratio of 1360 maternal deaths per 100 000 live births,[7 8] among the highest rates of stillbirth and neonatal death, and one of the lowest caesarean section rates.[9]

Multiple strategies to tackle maternal and neonatal death and stillbirths are being implemented by the Sierra Leone Ministry of Health and Sanitation (MoHS) and its partners. These strategies aim to increase

both skilled birth attendance and access to quality emergency obstetric and newborn care,[10] including caesarean section. The government has made strides towards developing a National Surgical, Obstetric, and Anesthesia Plan, and realises that an increased access to caesarean section also requires quality data to guide safe implementation and offset perioperative mortality.[6 11 12]

In 2015, the MoHS initiated the Maternal Death Surveillance and Response (MDSR) system[13] to identify, investigate and review every maternal death, and to propose interventions to prevent future deaths. In 2017, the first MDSR annual report was published, describing key characteristics of all reported maternal deaths from 2016.[14] However, the report did not provide population or facility rates of caesarean sections and did not provide any in-depth analysis of the clinical circumstances associated with caesarean section mortality. To date, no post-Ebola data exist on the frequency, distribution or outcomes of caesarean section in Sierra Leone.

The aim of this study was to describe the rate and perioperative mortality of caesarean sections in Sierra Leone in 2016, with trends over time and geographic distribution. The aim was also to compare characteristics of maternal deaths with and without caesarean section, and to describe correlations between operative volume and mortality rates. The purpose of this study was to promote optimisation of resources and to decrease maternal and fetal mortality.

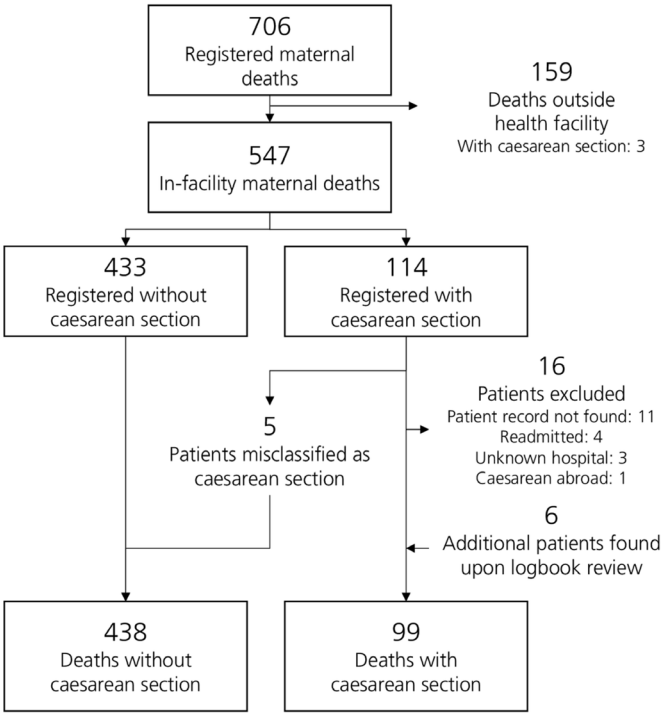


Figure 1 Inclusion and exclusion criteria. Maternal deaths with and without caesarean section in Sierra Leone, 2016.

METHODS

This is a retrospective study of reported in-facility maternal deaths in Sierra Leone in 2016, with a particular focus on deaths with caesarean section. Facility-level data on number of deliveries, caesarean sections and maternal deaths were combined with patient-level data on maternal mortality with and without caesarean section.

Data collection

All Sierra Leonean health facilities performing caesarean sections in 2016 were visited and numbers of caesarean sections, deliveries and maternal deaths reported in facility logbooks were recorded. The Sierra Leone MoHS provided access to the MDSR database, containing patient-level information on all maternal deaths notified through its system in 2016. Every maternal death after caesarean section was validated through on-site facility logbook review (including all available patient files, hospital logbooks, operating room logbooks and blood bank logbooks). Data were collected on paper forms, and transcribed.

The 2016 population was projected from 2015 population census data,[15] and the number of deliveries was derived using the World Development Indicators' estimated crude birth rate per 1000 people for 2016[16] (the crude birth rate was used as there may be significant under-reporting of births through the District Health Information System, particularly for births that did not occur in health facilities). The number of caesarean sections needed was calculated by multiplying the estimated number of deliveries—live births (as above)[15 16] and stillbirths (from a global analysis)[17]—with the expected need for caesarean section on maternal indication as a percentage of all deliveries (5.4%, from a previous study in West Africa by Dumont and colleagues in 2001).[18] The 2012 caesarean section rate from Bolkan *et al*, collected and calculated using the same methodology, was used for comparison over time.[9 19]

Inclusion and exclusion criteria

Facilities performing caesarean sections in 2016 were included in the facility-level analysis. To minimise the risk of under-reporting among facilities with no maternal deaths in the MDSR database, we cross-validated the findings with the number of maternal deaths from logbook data and excluded facilities with one or more maternal deaths according to logbooks, which had zero maternal deaths in the MDSR database. All patients in the MDSR database who died in a facility were included in the patient-level analysis. Maternal deaths outside facilities were excluded to improve comparability, and for patients who underwent caesarean section, deaths that occurred after discharge (including after readmission) were excluded in keeping with the standard definition of in-facility perioperative death. Logbooks were reviewed for all patients noted to have undergone caesarean section prior to, or at the time of death. Inclusion and exclusion

Table 1 Definitions of caesarean section rates and mortality rates

Rate	Definition
Population caesarean section rate	Number of caesarean sections/estimated number of births in the population (including stillbirths, based on crude birth rate, stillbirth rate and population)
In-facility caesarean section rate	Number of caesarean sections/number of in-facility deliveries (including stillbirths)
In-facility maternal mortality rate	Number of in-facility maternal deaths/number of in-facility births (including stillbirths)
Caesarean section mortality rate	Number of maternal deaths with caesarean section (death during or after the procedure, before discharge)/number of caesarean sections

criteria are summarised in figure 1. Caesarean section was defined by the provider.

Outcomes and independent variables

Primary outcomes were caesarean section rate and mortality rate. The definitions used for in-facility and population-level caesarean section rates are detailed in table 1, as are those used for mortality rates of all in-facility deliveries and those with caesarean section. To align with the WHO definition of perioperative mortality,[20] in-facility mortality was selected rather than 42-day mortality which is commonly used for maternal death reporting. Secondary outcomes were time from admission to death, time from operation to death, cause of death (as categorised by Say *et al*[2]), intraoperative findings and fetal outcome.

Facility-specific variables included facility type (peripheral health unit—primary healthcare centres including Maternal and Child Health Post, Community Health Post and Community Health Centre[21]—district hospital, or referral hospital), annual number of deliveries, number of maternal deaths and number of deaths associated with caesarean section. Patient-specific variables included age, gravidity, parity, number of antenatal care visits, referral history, indication for caesarean section, preoperative haemoglobin level, blood transfusion and number of units given, time from admission to start of operation, operation length, type of anaesthesia and type of surgical provider.

Statistical analysis

In-facility and population rates of caesarean section were stratified by district. In-facility rates were calculated for facilities performing caesarean section, and used to calculate a median value with IQR. All rates were provided as percentages. The rate of caesarean sections in 2016 was compared with that in 2012. Characteristics of maternal deaths with and without caesarean section were compared using the Mann-Whitney U test for non-normally distributed continuous variables and Fisher's exact test for binary outcomes. Time from admission to caesarean section, and time from caesarean section to death, were presented in Kaplan-Meier plots, with patients censored at death or at the time of discharge. Facilities were grouped based on their respective caesarean section mortality rate, and differences in patient characteristics, clinical management and outcomes were analysed using Kruskal-Wallis test for continuous variables and Fisher-Freeman-Halton test for categorical and binary outcomes. The association between caesarean section mortality and the rate and volume of caesarean section (using its common logarithm) was described using univariate linear regressions, with β and 95% CIs. Statistical analysis was done in R (V.3.5.1, The R Project for Statistical Computing).

Ethical considerations

Ethical approval was granted by the Sierra Leone Ethics and Scientific Review Committee to collect facility-level data (16 May 2016) and patient-level data (10 August 2017). Informed written consent was sought from the medical superintendent of each facility ahead of data collection. Personal identifiers were transcribed and kept on a password-protected computer.

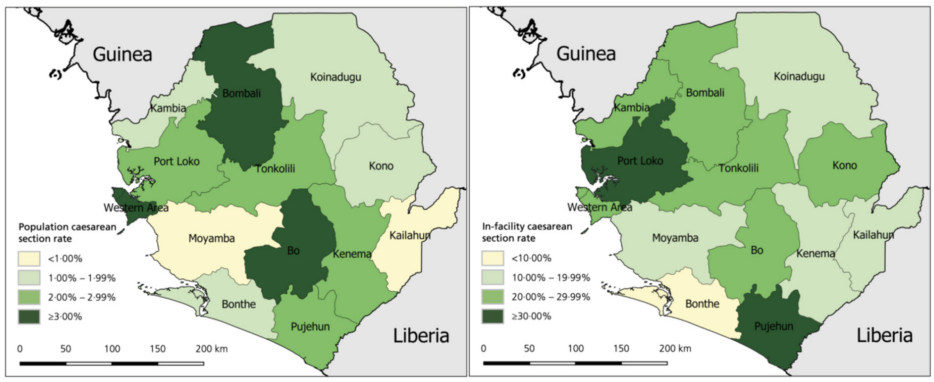
Patient and public involvement

We did not involve patients or the public in our work.

RESULTS

In 2016, a total of 7357 caesarean sections were performed in 36 healthcare facilities in Sierra Leone (figure 2). This corresponds to a population caesarean section rate of 2.9% of all live births—a 0.8 percentage point increase from the 2.1% (n=4868) in 2012, equating to a 35% relative increase or a 7.7% annual growth rate. Compared with the estimated 14 173 (low to high estimate 9449–17 060) caesarean sections needed for maternal indications in 2016, 52% (43%–78%) were performed (online supplementary figure 1). District rates ranged from 0.4% to 5.2%, and the overall in-facility rate was 23% (median 23% (IQR 14%–33%)) (figure 2).

Of the 537 reported in-facility maternal deaths in 2016 presented in figure 1, 435 (81%) occurred in facilities performing caesarean sections, and 99 (18%) occurred during or after caesarean section. Seven caesarean section deaths were excluded, three occurred outside a health facility, with an unknown date of operation, and four occurred after readmission. The caesarean section mortality rate was 1.5% (99 deaths in 6748 caesarean sections) with a facility median of 0.7% (IQR 0.0–2.2). Over half of all caesarean sections were performed in facilities with a reported caesarean section mortality rate of 2% or less (online supplementary table 1).



District	Population live births*	Deliveries in facility	Caesarean sections	Caesarean section rate	
				Population	In-facility
Bo	20 790	4 883	1 069	5·1%	22%
Bombali	21 912	3 189	778	3·6%	24%
Bonthe	7 253	1 118	78	1·1%	7%
Kailahun	19 016	1 010	169	0·9%	17%
Kambia	12 481	672	157	1·3%	23%
Kenema	22 033	2 502	448	2·0%	18%
Koinadugu	14 789	1 133	158	1·1%	14%
Kono	18 283	1 043	290	1·6%	28%
Moyamba	11 509	361	51	0·4%	14%
Port Loko	22 231	1 923	580	2·6%	30%
Pujehun	12 516	939	364	2·9%	39%
Tonkolili	19 199	1 879	403	2·1%	21%
Western Area**	54 198	10 962	2 812	5·2%	26%
Total	256 211	31 614	7 357	2·9%	23%

* From estimated 2016 population[14] and Crude Birth Rate[15] (35.0 per 1 000 people)
**Western Area Urban and Rural combined

Figure 2 Caesarean section rates in Sierra Leone 2016. In-facility caesarean section rate (proportion of in-facility births as caesarean section), and population caesarean section rate (proportion of all live births as caesarean section).

Of the 99 patients who died during or after caesarean section, most had been referred from another facility (n=53, 58%; primarily peripheral health units). Most women who died were preoperatively anaemic (median haemoglobin level 90 g/L (IQR 7.4–10.5)), and a majority (n=74, 75%) received one or more blood transfusions (table 2). The three most common indications for surgery were obstructed labour (n=42, 42%), pre-eclampsia or eclampsia (n=25, 25%) and haemorrhage (n=22, 22%). Sixteen caesarean sections (16%) were performed for malpresentations and twins/triplets, and there were no caesarean sections performed for fetal distress. Over half were operated within 6 hours of admission. The majority of caesarean sections were performed by medical officers (55%), with one-fourth (24%) performed by either fully trained surgical assistant community health officers (SACHO) or SACHO trainees, and 8% performed by a specialist obstetrician (table 2). A majority (n=77, 80%) had general anaesthesia (table 2); ketamine was used in 25 of the 32 patients where the anaesthesia agent was recorded. In 23 cases (22%) uterine rupture was diagnosed, and five of these women were known to have undergone a previous caesarean section. While most patients died after leaving the operating room, over 50% died within 10 hours after surgery (figure 3 and table 3). The most common causes of death were haemorrhage and hypertensive disorders; 73% of deaths with caesarean section were caused by haemorrhage compared with 44% of deaths without caesarean section (p<0.001, table 3). In one case, transfusion reaction was registered as cause of death. In 44 of the maternal deaths with caesarean section, fetal death was recorded, corresponding to 59% of patients with a known fetal outcome (table 3). For most of the available patient characteristics, no statistically significant difference was found between women who died in-facility with or without undergoing caesarean section, however women who died without caesarean section generally had higher parity (p=0.005), were more often referred from home (rather than another facility, p<0.001) and spent less time in the facility before passing away (p=0.02, table 3).

Facilities with higher caesarean section mortality rate had longer operating time (p<0.001), longer time from start of operation to death (p<0.001) and higher rates of haemorrhage as cause of death (p=0.05) (online supplementary table 2). There was a significant association between caesarean section mortality rate and maternal mortality rate (β=1.64 (95% CI 0.99 to 2.29), p<0.001), and between maternal mortality rate and the log transformed volume of caesarean sections (β=0.80 (95% CI 0.09 to 1.51), p=0.03). Caesarean section mortality rate was not significantly associated with the

Table 2 Patient characteristics and clinical management of women who died during or after caesarean section in Sierra Leone in 2016

Age	
Median (IQR), n=99	27 (20–32)
15–19	14 (14%)
20–24	24 (24%)
25–34	44 (44%)
≥35	17 (17%)
Gravidity	
Median (IQR), n=97	3 (1–5)
1	25 (26%)
2–5	56 (58%)
≥6	16 (16%)
Parity	
Median (IQR), n=96	2 (0–4)
0	25 (26%)
1–4	56 (58%)
≥5	15 (16%)
Number of antenatal care visits	
Median (IQR), n=56	3 (2–3)
0	6 (11%)
1	4 (7%)
2–3	36 (64%)
≥4	10 (18%)
Referred from	
Home	39 (43%)
Peripheral health unit	51 (56%)
Other hospital	2 (2%)
Unknown	7 (7%)
Preoperative haemoglobin level	
Median (IQR), g/L, n=49	90 (74–105)
Indication for caesarean section*	
Obstructed labour	42 (42%)
Pre-eclampsia/eclampsia	25 (25%)
Haemorrhage	22 (22%)
Placental abruption	10 (10%)
Malpresentation	9 (9%)
Twins/triplets	7 (7%)
Uterine rupture	7 (7%)
Previous CS	6 (6%)
Type of surgical provider	
Medical officer	53 (55%)
Surgical training programme student	13 (13%)
Surgical assistant community health officer	11 (11%)
Specialist obstetrician	8 (8%)
House officer	7 (7%)
Other associate clinician	5 (5%)
Unknown	2 (2%)
Time from admission to start of operation	
Median (IQR), hours, n=84	5.8 (2.0–21.3)
Operation length	
Median (IQR), min, n=67	49 (33 – 69)
Additional procedures registered	
Hysterectomy	14 (14%)
B-Lynch procedure	3 (3%)
Blood transfusion	
Patients transfused (proportion), n=99	74 (75%)
Number of units transfused	
Median (IQR), n=93	1 (1–2)
Type of anaesthesia	
General	72 (75%)
Spinal	19 (20%)
Spinal and general	5 (5%)
Unknown	3 (3%)

*Multiple indications given for some patients; indications with ≤5 occurrences excluded; percentages may add up to above 100% due to rounding or patients appearing in multiple categories.
CS, caesarean section.

per facility volume (log transformed, p=0.35) or rate (p=0.08) of caesarean section; maternal mortality rate was not significantly associated with caesarean section rate (p=0.5) (online supplementary figure 2).

DISCUSSION

In this study of all caesarean sections and all reported in-facility maternal deaths in Sierra Leone, we found an overall caesarean section rate of 2.9%, and a perioperative mortality rate of 1.5%. Our study is the first to present nationwide data on caesarean section mortality in Sierra Leone.

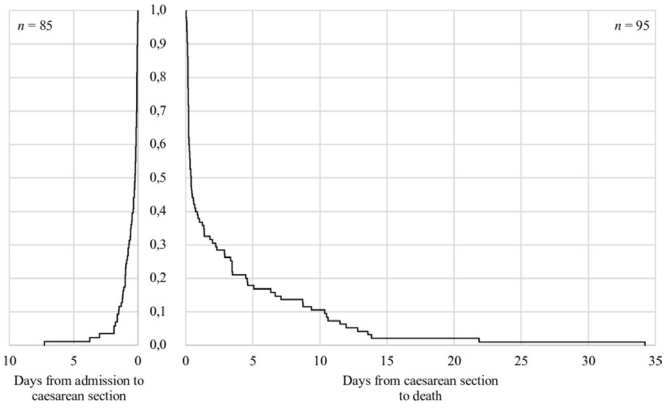


Figure 3 Time from admission to caesarean section and time from caesarean section to death among women who died in-facility during or after caesarean section in Sierra Leone in 2016.

Table 3 In-facility maternal deaths with and without caesarean section in Sierra Leone in 2016

	With caesarean section n=99	Without caesarean section n=438	P value
Age			
Median (IQR)	27 (20–32)	27 (21–32)	0.76*
<15	14 (14%)	71 (16%)	
15–24	24 (24%)	88 (20%)	
25–34	44 (44%)	190 (44%)	
≥35	17 (17%)	86 (20%)	
Unknown	0 (0%)	3 (0.7%)	
Gravidity			
Median (IQR)	3 (1–5)	3 (2–6)	0.10*
1	25 (26%)	86 (24%)	
2–5	56 (58%)	197 (54%)	
≥6	16 (16%)	81 (22%)	
Unknown	2 (2%)	74 (17%)	
Parity			
Median (IQR)	2 (0–4)	3 (1–5)	0.005*
0	25 (26%)	57 (19%)	
1–4	56 (58%)	156 (53%)	
≥5	15 (16%)	80 (27%)	
Unknown	3 (3%)	145 (33%)	
Number of antenatal care visits			
Median (IQR)	3 (2–3)	3 (1–3)	0.55*
0	6 (11%)	30 (13%)	
1	4 (7%)	31 (13%)	
2–3	36 (64%)	121 (51%)	
≥4	10 (18%)	56 (24%)	
Unknown	43 (43%)	200 (46%)	
Referred from			<0.001†
Other hospital	2 (2%)	6 (2%)	
Peripheral health unit	51 (56%)	89 (33%)	
Home	39 (43%)	173 (65%)	
Unknown	7 (7%)	170 (39%)	
Time from admission to death			
Median (IQR) number of days	1.0 (0.3–3.7)	0.7 (0.2–2.3)	0.02*
Unknown	1 (1%)	144 (33%)	
Time from start of operation to death			
Median (IQR), hours, n=95	9.5 (4.4–81.5)	N/A	
Unknown	4 (4%)	N/A	
Intraoperative findings			
Uterine rupture	23 (22%)	N/A	
Placental abruption	11 (10%)	N/A	
Cause of death‡			
Haemorrhage	64 (73%)	184 (44%)	<0.001§
Hypertensive disorders	20 (23%)	72 (17%)	0.29§
Sepsis	12 (14%)	47 (11%)	0.58§

Continued

Table 3 Continued

	With caesarean section	Without caesarean section	
	n=99	n=438	P value
Embolism	1 (1%)	0	0.32§
Other direct causes	0	19 (5%)	0.03§
Indirect causes	11 (12%)	93 (22%)	0.04§
Abortion	0	12 (3%)	0.14§
Unknown	11 (11%)	24 (5%)	
Fetal death¶			
Number of stillbirths (proportion)	44 (59%)	95 (46%)	0.06§
Unknown	25 (25%)	232 (53%)	

*Mann-Whitney U test.
†χ^2 test.
‡Categories according to Say *et al*,[2] several contributing causes of death were noted for some patients.
§Fisher's exact test.
¶Fetal death included cases of death of one of two twins, and undelivered fetuses, and molar pregnancies were excluded; percentages may add up to above 100% due to rounding or patients appearing in multiple categories.
N/A, not applicable.

The caesarean section rate

The average annual growth rate for caesarean sections was 7.7% between 2012 and 2016, almost twice the global average rate of increase for 2000–2015.[6] Still, the caesarean section rate remained among the lowest in the world.[6] There was an almost 15-fold difference between the lowest and highest district rates; such maldistribution is common across low/middle-income countries.[22] Many barriers contribute to delays in reaching and accessing care,[23] including financial barriers (in spite of the Free Healthcare Initiative for mothers and children under 5[24]), cultural and community factors, lack of transportation, and poor quality of care, long waiting times and in some cases disrespectful treatment at health facilities. Previous studies suggest that many women do not wish to deliver in health facilities, and only seek help after complications occur. Childbirth is seen as a natural process and traditional birth attendants are generally more trusted than health professionals. Indeed, addressing cultural barriers was also listed as a recommendation in the 2016 MDSR report.[14 25–30] While 54% of women in Sierra Leone deliver in a healthcare facility,[7] many had to be referred, and some women spent hours or days in the facility before undergoing surgery. In this study, we were not able to determine for how long patients waited after the decision to operate (the 'decision-to-incision interval'), however, it is likely that there were delays, which should be further investigated in future studies.

The caesarean section mortality rate

The in-facility perioperative mortality of caesarean section was in line with previous studies in West Africa,[31] but higher than the risk of maternal death in some other countries in sub-Saharan Africa, with recorded maternal mortality rates of between 5.43 per 1000 operations in a 2016 prospective cohort study in 22 countries,[32] and 10.9 per 1000 in a recent meta-analysis.[33] It was also similar to the rate of 1.3% (16 in 1274) recorded among women who underwent caesarean section in nine hospitals in Sierra Leone between October 2016 and May 2017.[34] Compared with rates of 0.05% in some high-income countries,[35] mortality following caesarean section is about 30 times higher in Sierra Leone. There was also wide variation in mortality rates between facilities, and fetal death was common. Several factors likely contributed to maternal and fetal deaths, particularly low access to emergency obstetric and neonatal care and late presentation, but also resource constraints leading to insufficient quality of emergency obstetric care, including lack of appropriate monitoring of fetal status intrapartum.[36] Many women in this study were already severely ill on presentation from untreated complications of pregnancy—indeed, many of the indications for surgery are themselves life threatening, making it difficult to distinguish the role of the care provided from the underlying, often severe, morbidity. Most women were referred from another facility (mostly peripheral health units) and were anaemic and had obstructed labour. The incidence of uterine rupture was very high among the women who died during or after caesarean section (22%). In 2017, uterine rupture accounted for 7% of all reported maternal deaths in Sierra Leone[37]—very high numbers compared with global incidence data.[38] Delays causing women to present for caesarean section after many days of obstructed labour, lack of ready access to caesarean section and inappropriate use of oxytocin have all been cited as potential contributors to maternal and fetal deaths in the first two MDSR reports from Sierra Leone.[14 37] In some cases, a history of previous caesarean section likely contributed to the development of uterine rupture.[39] Since 2018, updated guidelines have been made available to health workers in Sierra Leone to improve management.[40]

Caesarean section has known risks[41] of both immediate[42–44] and long-term complications,[45] and rapid increases in the volume of surgery must be coupled with adequate training of clinicians and robust quality controls, among other interventions.[6 11] Indeed, we believe that most of the caesarean sections in this review were performed to save lives—a prospective study of 1274 patients undergoing caesarean section in nine hospitals in Sierra Leone in 2016–2017 showed that most procedures are done as an emergency procedure and on maternal indication[34]—but clinical audits are needed to ensure caesarean sections are not carried out unnecessarily, and attention should be given to the possibility that the procedure itself may contribute to mortality, in the short and long terms.[41]

Perioperative care

While it is not possible to infer anything about the quality or safety of the anaesthesia provided for those who died during or after the procedure from our data, perioperative care plays a crucial role for decreasing perioperative mortality. In one systematic review, 13.8% of maternal deaths after caesarean section were attributed to complications of anaesthesia, with general anaesthesia (the predominant form in this study) having the highest risk of death.[46] Spinal anaesthesia is the most common form of anaesthesia in caesarean sections in Sierra Leone,[47] yet a majority of those who died in this study had general anaesthesia. This may be in part explained by the fact that hypotension and haemorrhage are regarded as contraindications to spinal anaesthesia, but in some cases lack of staff and supplies may have contributed to the decision to give general anaesthesia. Further research is needed to better understand the choice of anaesthesia method. Furthermore, it should be noted that in most cases, ketamine was the anaesthesia agent used, and in our experience, this is often used without intubation in Sierra Leone. Although it is widely known that patients maintain respiratory drive and airway protective reflexes with ketamine anaesthesia, further research is also needed to address anaesthesia safety. The capacity to provide safe anaesthesia has been reported as very low, even as nurse anaesthetists are being trained to increase access to anaesthesia across the country.[48] Most facilities in Sierra Leone lack the human resources and infrastructure to provide care for patients who are critically ill, which may contribute further to the high perioperative mortality.[49]

Blood transfusion

Three out of four of the women who later died during or after caesarean section received blood transfusion. However, most received only one transfusion, which is usually insufficient to treat major postpartum haemorrhage. Indeed, hospitals in Sierra Leone struggle with providing sufficient blood for transfusion. Additionally, there may be challenges with providing cross-matching of blood, and safe blood transfusion may not always be available (according to the 2017 Service Availability and Readiness Assessment report, only 27% of facilities designated as comprehensive emergency obstetric care facilities carried out cross-match testing).[36] Blood transfusion reactions may therefore be an unrecognised contributor to some of the maternal deaths—in at least one case, a transfusion reaction was registered as cause of death, demanding that particular attention be paid to the provision of safe blood transfusion services.

Workforce and training

In Sierra Leone, caesarean sections are carried out by both physicians and associate clinicians,[50] and most of the anaesthesia is provided by nurse anaesthetists.[48] Such task sharing has a long history on the African continent,[51–53] particularly for caesarean delivery, and in many cases with good results.[53] In Sierra Leone, the role of task sharing is increasing, as an increasing proportion of all caesarean sections are carried out by SACHOs[50 54]—a cadre of associate physicians trained in surgery for 3 years after basic training as a community health officer and an obligatory period of clinical practice. Only about 40 physicians graduate from Sierra Leone's only medical school each year,[55] and many of these physicians leave the country to pursue other opportunities including postgraduate specialist training.[56] There is only one postgraduate training programme in the country, in general surgery,[55] and none yet in obstetrics, so task sharing for caesarean sections will likely continue to play an important role in expanding access to surgical obstetric care for many years to come. Although none of the caesarean sections in this study were carried out by midwives, they play a crucial role in managing labour, including leading up to and following a caesarean section.

Peripheral health units and referral for caesarean section

Most of the women who died were referred from peripheral health units, and while we were not able to collect data on events prior to admission to hospital, it is clear that these clinics play a decisive role in diagnosing, managing and referring patients. Yet, many of them lack staff and supplies,[36] and the referral itself can be hampered by lack of access to transportation.

Overuse and alternatives to caesarean section

Care should be taken to avoid overuse of caesarean sections—in India, for example, one study describes financial incentives for doctors to perform caesarean section, and incentives for patients (painless delivery, control of date and time, and so on) to accept the procedure, leading to unnecessary procedures.[57] Surgical delivery must not be the only available solution for complicated deliveries, yet assisted vaginal delivery (vacuum extraction or other instrumental delivery) is underused in Sierra Leone.[36 58 59] In some cases, such methods may be safer alternatives to caesarean section, and the option of symphysiotomy has been discussed in the obstetric literature.[60] Furthermore, in certain cases of intrauterine fetal death, destructive operations (such as craniotomy) could

have been an alternative to caesarean section, to spare the mother the risks and complications of the procedure and the increased risk of complications from subsequent deliveries. Providing postgraduate training in obstetrics including training in assisted vaginal delivery (and possibly destructive operations when no other options remain) would contribute to increasing the use of alternative delivery methods. While not directly addressed in this study, the role of fetal monitoring during delivery should also be mentioned as a crucial tool for decreasing neonatal mortality and morbidity. In our experience, such monitoring is underused in Sierra Leone.

The MDSR system

The MDSR system was first implemented in Sierra Leone in 2015, and while it may not capture all maternal deaths, it does provide detailed information on individual cases and has led to improved service delivery in some countries.[61] Fully implemented, it promises real-time data and actionable recommendations to end preventable maternal deaths.[62] In addition to maternal death reviews, clinical audits could help ensure improvements in the quality of perioperative care and optimal use of scarce resources.[63 64] To allow more standardised reporting, data collection for caesareans should follow the Robson 10 group classification system that relies on variables including parity, fetal presentation, gestational age, induced or spontaneous labour and previous caesarean.[65 66] In the context of an increasing rate of surgery in Sierra Leone overall, a 'Surgical Mortality and Morbidity Surveillance and Response' framework could be employed for monitoring perioperative mortality of other surgical procedures in areas with particularly high perioperative mortality.

Strengths and limitations

This study has several limitations. We did not capture non-lethal morbidity, or long-term outcomes after discharge. Our analyses are based on data compiled from the MDSR database and paper-based logbooks, with possible reporting bias, including possible under-reporting of maternal death,[14] and over-reporting of the number of procedures carried out as a result of performance-based financing, introduced in Sierra Leone in 2011 and abandoned in early 2016.[67 68] The MDSR database had recently been introduced in 2016, reporting a lower number of maternal deaths than expected based on available maternal mortality estimates,[8] in turn based on data from the 2013 Demographic and Health Survey.[7] Under-reporting is likely part of the reason, particularly of deaths outside of facilities. By focusing on in-facility deaths, and validating reported deaths through logbook review, we sought to minimise the effect of under-reporting. While we are not aware of any studies investigating the quality of registry data in Sierra Leone, we know from experience that in most facilities there is a routine of reporting procedures; nevertheless, misdiagnosis and reporting errors may have influenced the quality of our registry data. By focusing on in-facility deaths and validating reported data through patient files, operating room logbooks and blood bank logbooks, we sought to ensure optimal data quality for the maternal deaths with caesarean section.

We chose to use the WHO perioperative mortality definition,[20] which excludes patients who died after discharge or on readmission to hospital; indeed, this may have led to an underestimated mortality rate. While the true number of deaths that occurred after discharge can only be estimated, van Duinen *et al* reported that among 1274 patients who underwent caesarean section in nine hospitals in 2016–2017, three of the 16 maternal deaths occurred within 30 days after discharge.[34] Compared with the three deaths outside health facilities following caesarean section reported through the MDSR system in 2016, this suggests that the in-facility perioperative mortality definition is more robust to under-reporting of deaths outside hospitals. Many facilities did not report any deaths during or after caesarean section at all, which could indicate under-reporting from those facilities. Another limitation is that we could not compare those who died to those who did not since we did not have patient-level data on all caesarean sections. When comparing the rate of surgery in 2012 and 2016, we used the same methodology in both years to ensure comparability, but are aware that there may be uncertainties in the official demographic data used (crude birth rate and population). In our calculation of the unmet need for caesarean section, we used a previously published estimate of the population need for caesarean section, but there is currently no global consensus on the exact population need for the procedure.

This is the first national-level study on caesarean section perioperative mortality in Sierra Leone, and despite limitations, our combination of patient-level and facility-level data allowed us to establish a baseline for further investigation of caesarean sections in the country. We were also able to calculate the caesarean section rate for 2016, building on previous research by Bolkan *et al*.[9]

Next steps

More access to caesarean sections for maternal and neonatal indications is needed to further decrease maternal mortality in Sierra Leone, especially in underserved areas, but increasing the caesarean section rate must go hand in hand with strengthening other components of emergency obstetric and neonatal care. Ensuring timely presentation, offering assisted vaginal delivery when indicated and improving perioperative and anaesthesia care, including fetal monitoring, are potential areas for development. Alongside continuous reporting and review of maternal deaths, periodic clinical audits could help monitor that the right indications are used. We hope that findings from this analysis will help improve perioperative care so that pregnant women have access to timely and safe caesarean sections when needed.

Author affiliations
[1]Department of Clinical Sciences Lund, WHO Collaborating Centre for Surgery and Public Health, Lund University Faculty of Medicine, Lund, Sweden
[2]Department of Public Health Sciences, Karolinska Institute, Stockholm, Sweden
[3]Karolinska University Hospital, Solna, Sweden
[4]College of Medicine and Allied Health Sciences, University of Sierra Leone, Freetown, Sierra Leone
[5]Department of Cancer Research and Molecular Medicine, Norwegian University of Science and Technology, Trondheim, Norway
[6]Department of Surgery, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway
[7]Sierra Leone Ministry of Health and Sanitation, Freetown, Sierra Leone
[8]World Health Organization Sierra Leone, Freetown, Sierra Leone
[9]Department of Obstetrics and Gynecology, Institute of Clinical Sciences Lund, Skåne University Hospital, Lund University, Lund, Sweden
[10]Department of Obstetrics and Gynaecology, Princess Christian Maternity Hospital, Freetown, Sierra Leone
[11]Department of Anaesthesia, Princess Christian Maternity Hospital, Freetown, Sierra Leone
[12]Department of Anaesthesia, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway
[13]Department of Paediatric Surgery, Skåne University Hospital Children's Hospital, Lund, Sweden

Acknowledgements The authors acknowledge the important contributions by Katinka Taule, Johanne Knoph Sandvand, Kakpama SK Jusu, Mohamed Alieu Shmr and Abubakar Dumbuya in collecting data on the number of caesarean sections, and Joycee Pormai and Abdul Kamara who assisted in collecting logbook data on the women who died during or after caesarean section. We are also grateful to those who have contributed to the implementation of the Maternal Death Surveillance and Response system.

Contributors HH and LH conceived the study and developed the study design together with MMK, HAB, AvD, FF, BH and HL. HH and HL sought ethical approval and oversaw data collection. BH, FF, SC and SS facilitated access to the MDSR database. HL led the collection of facility data and MMK led the logbook review for patients who died with caesarean section. HH wrote the first draft of the manuscript and analysis, and developed the final manuscript with significant input from all coauthors, in particular AvD, MMK, FF, JL, HL, SRH and LH. All authors read and approved the final version.

Funding This study was funded by Lund University and Norwegian University of Science and Technology.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Sierra Leone Ethics and Scientific Review Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

REFERENCES

1. Alkema L, Chou D, Hogan D, *et al*. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the un maternal mortality estimation Inter-Agency group. *Lancet* 2016;387:462–74.
2. Say L, Chou D, Gemmill A, *et al*. Global causes of maternal death: a who systematic analysis. *The Lancet Global Health* 2014;2:e323–33.
3. Ye J, Betrán AP, Guerrero Vela M, *et al*. Searching for the optimal rate of medically necessary cesarean delivery. *Birth* 2014;41:237–44.
4. World Health Organization. *WHO statement on caesarean section rates*. Geneva, Switzerland: WHO, 2015.
5. Betran AP, Torloni MR, Zhang JJ, *et al*. Who statement on caesarean section rates. *BJOG: Int J Obstet Gy* 2016;123:667–70.
6. Boerma T, Ronsmans C, Melesse DY, *et al*. Global epidemiology of use of and disparities in caesarean sections. *Lancet* 2018;392:1341–8.
7. Statistics Sierra Leone, ICF International. *Sierra Leone demographic and health survey 2013*. Freetown, Sierra Leone and Rockville, Maryland, USA: Statistics Sierra Leone, ICF International, 2014.
8. WHO, UNICEF, UNFPA. *Trends in maternal mortality: 1990 to 2015: estimates by who, UNICEF, UNFPA, world bank group and the United nations population division*. Geneva, Switzerland: World Health Organization, 2015.
9. Bolkan HA, Von Schreeb J, Samai MM, *et al*. Met and unmet needs for surgery in Sierra Leone: a comprehensive, retrospective, countrywide survey from all health care facilities performing operations in 2012. *Surgery* 2015;157:992–1001.
10. World Health Organization, United Nations Population Fund, UNICEF. *Monitoring emergency obstetric care: a Handbook*. Geneva, Switzerland: WHO, 2009.
11. Betrán AP, Temmerman M, Kingdon C, *et al*. Interventions to reduce unnecessary caesarean sections in healthy women and babies. *Lancet* 2018;392:1358–68.
12. Kruk ME, Gage AD, Arsenault C, *et al*. High-Quality health systems in the sustainable development goals era: time for a revolution. *Lancet Glob Health* 2018;6:e1196–252.
13. World Health Organization. *Maternal death surveillance and response: technical guidance information for action to prevent maternal death*. Geneva, Switzerland: WHO, 2013.
14. Directorate of Reproductive and Child Health, Ministy of Health and Sanitation. *Maternal death surveillance and response annual report 2016*. Freetown, Sierra Leone: Ministry of Health and Sanitation, 2017.
15. Statistics Sierra Leone. *2015 population and housing census summary of final results: planning a better future*. Freetown, Sierra Leone: Statistics Sierra Leone, 2016.
16. World Bank. Birth rate, crude (per 1,000 people) Washington, D.C, USA: the world bank group, 2018. Available: https://data.worldbank.org/indicator/SP.DYN.CBRT.IN?locations=SL&view=chart
17. Blencowe H, Cousens S, Jassir FB, *et al*. National, regional, and worldwide estimates of stillbirth rates in 2015, with trends from 2000: a systematic analysis. *The Lancet Global Health* 2016;4:e98–108.
18. Dumont A, de Bernis L, Bouvier-olle M-H, *et al*. Caesarean section rate for maternal indication in sub-Saharan Africa: a systematic review. *Lancet* 2001;358:1328–33.
19. Bolkan HA, von Schreeb J, Samai MM, *et al*. Rates of caesarean section and total volume of surgery in Sierra Leone: a retrospective survey. *Lancet* 2015;385(Suppl 2).
20. World Health Organization. *Global reference list of 100 core health indicators (plus health-related SDGs)*. Geneva: World Health Organization, 2018.
21. Government of Sierra Leone. *Ministry of health and sanitation. basic package of essential health services*. Freetown, Sierra Leone: Government of Sierra Leone, 2015.
22. Boatin AA, Schlotheuber A, Betran AP, *et al*. Within country inequalities in caesarean section rates: observational study of 72 low and middle income countries. *BMJ* 2018;360.
23. Thaddeus S, Maine D. Too far to walk: maternal mortality in context. *Soc Sci Med* 1994;38:1091–110.
24. Witter S, Brikci N, Harris T, *et al*. The free healthcare initiative in Sierra Leone: evaluating a health system reform, 2010-2015. *Int J Health Plann Manage* 2018;33:434–48.
25. Sharkey A, Yansaneh A, Bangura PS, *et al*. Maternal and newborn care practices in Sierra Leone: a mixed methods study of four underserved districts. *Health Policy Plan* 2017;32:151–62.
26. Treacy L, Bolkan HA, Sagbakken M. Distance, accessibility and costs. decision-making during childbirth in rural Sierra Leone: a qualitative study. *PLoS One* 2018;13:e0188280.
27. Oyerinde K, Harding Y, Amara P, *et al*. Barriers to uptake of emergency obstetric and newborn care services in Sierra Leone: a qualitative study. *J Community Med Health Educ* 2012;2:1–8.
28. Oyerinde K, Harding Y, Amara P, *et al*. A qualitative evaluation of the choice of traditional birth attendants for maternity care in 2008 Sierra Leone: implications for universal skilled attendance at delivery. *Matern Child Health J* 2013;17:862–8.
29. Nathaniel-Wurie L, Martin G, Cooper G, *et al*. PS33 Health-Seeking Behaviour in the Era of Free Healthcare in Urban Slums in Sierra Leone. *J Epidemiol Community Health* 2012;66(Suppl 1):A51.1–A51.
30. Herschderfer K, Kd K, EMb S, *et al*. *Barriers and promising interventions for improving maternal and newborn health in Sierra Leone*. 1st edn. Amsterdam, Netherlands: KIT Publishers, 2012.
31. Uribe-Leitz T, Jaramillo J, Maurer L, *et al*. Variability in mortality following caesarean delivery, appendectomy, and groin hernia repair in low-income and middle-income countries: a systematic

review and analysis of published data. *Lancet Glob Health* 2016;4:e165–74.
32. Bishop D, Dyer RA, Maswime S, *et al*. Maternal and neonatal outcomes after caesarean delivery in the African surgical outcomes study: a 7-day prospective observational cohort study. *Lancet Glob Health* 2019;7:e513–22.
33. Sobhy S, Arroyo-Manzano D, Murugesu N, *et al*. Maternal and perinatal mortality and complications associated with caesarean section in low-income and middle-income countries: a systematic review and meta-analysis. *Lancet* 2019;393:1973–82.
34. van Duinen AJ, Kamara MM, Hagander L, *et al*. Caesarean section performed by medical doctors and associate clinicians in Sierra Leone. *BJS* 2019;106:e129–37.
35. Kallianidis AF, Schutte JM, van Roosmalen J, *et al*. Maternal mortality after cesarean section in the Netherlands. *Eur J Obstet Gynecol Reprod Biol* 2018;229:148–52.
36. Government of Sierra Leone Ministry of Health and Sanitation. *Summary report of the 2017 SARA plus in Sierra Leone: service availability and readiness assessment (SARA), quality of care survey, and data quality review*. Freetown, Sierra Leone: MOHS, 2018.
37. Directorate of Reproductive and Child Health, Ministy of Health and Sanitation. *Maternal death surveillance and response annual report 2017*. Freetown, Sierra Leone: Ministry of Health and Sanitation, 2018.
38. Hofmeyr GJ, Say L, Gülmezoglu AM. Who systematic review of maternal mortality and morbidity: the prevalence of uterine rupture. *BJOG* 2005;112:1221–8.
39. Guise J-M, McDonagh MS, Osterweil P, *et al*. Systematic review of the incidence and consequences of uterine rupture in women with previous caesarean section. *BMJ* 2004;329:19–25.
40. Directorate of Reproductive and Child Health, Ministy of Health and Sanitation. *National protocols and guidelines for emergency obstetric and newborn care*. Freetown, Sierra Leone: Ministy of Health and Sanitation, 2018.
41. Sandall J, Tribe RM, Avery L, *et al*. Short-Term and long-term effects of caesarean section on the health of women and children. *Lancet* 2018;392:1349–57.
42. Deneux-Tharaux C, Carmona E, Bouvier-Colle M-H, *et al*. Postpartum maternal mortality and cesarean delivery. *Obstetrics & Gynecology* 2006;108:541–8.
43. Abalos E, Addo V, Brocklehurst P, *et al*. Caesarean section surgical techniques (CORONIS): a fractional, factorial, unmasked, randomised controlled trial. *Lancet* 2013;382:234–48.
44. Lilford RJ, van Coeverden de Groot HA, Moore PJ, *et al*. The relative risks of caesarean section (intrapartum and elective) and vaginal delivery: a detailed analysis to exclude the effects of medical disorders and other acute pre-existing physiological disturbances. *Br J Obstet Gynaecol* 1990;97:883–92.
45. Keag OE, Norman JE, Stock SJ. Long-Term risks and benefits associated with cesarean delivery for mother, baby, and subsequent pregnancies: systematic review and meta-analysis. *PLoS Med* 2018;15:e1002494.
46. Sobhy S, Zamora J, Dharmarajah K, *et al*. Anaesthesia-related maternal mortality in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet Global Health* 2016;4:e320–7.
47. Lonnee H. *Personal communication (unpublished data)*, 2018.
48. Vaughan E, Sesay F, Chima A, *et al*. An assessment of surgical and anesthesia staff at 10 government hospitals in Sierra Leone. *JAMA Surg* 2015;150:237–44.
49. Kingham TP, Kamara TB, Cherian MN, *et al*. Quantifying surgical capacity in Sierra Leone: a guide for improving surgical care. *Arch Surg* 2009;144:122–7.
50. Bolkan HA, Hagander L, von Schreeb J, *et al*. The surgical workforce and surgical provider productivity in Sierra Leone: a countrywide inventory. *World J Surg* 2016;40:1344–51.
51. Chu K, Rosseel P, Gielis P, *et al*. Surgical task shifting in sub-Saharan Africa. *PLoS Med* 2009;6:e1000078.
52. Dawson AJ, Buchan J, Duffield C, *et al*. Task shifting and sharing in maternal and reproductive health in low-income countries: a narrative synthesis of current evidence. *Health Policy Plan* 2014;29:396–408.
53. Schneeberger C, Mathai M. Emergency obstetric care: making the impossible possible through task shifting. *Int J Gynaecol Obstet* 2015;131(Suppl 1):S6–9.
54. Bolkan HA, van Duinen A, Waalewijn B, *et al*. Safety, productivity and predicted contribution of a surgical task-sharing programme in Sierra Leone. *Br J Surg* 2017;104:1315–26.
55. Sierra Leone Ministry of Health and Sanitation. *Human resources for health strategy 2017-2021*. Freetown, Sierra Leone: MOHS, 2017.
56. Lantz A, Holmer H, Finlayson S, *et al*. International migration of surgeons, anaesthesiologists, and obstetricians. *The Lancet Global Health* 2015;3(Suppl 2):s11–12.
57. Singh P, Hashmi G, Swain PK. High prevalence of cesarean section births in private sector health facilities- analysis of district level household survey-4 (DLHS-4) of India. *BMC Public Health* 2018;18:613.
58. Oyerinde K, Harding Y, Amara P, *et al*. The status of maternal and newborn care services in Sierra Leone 8 years after ceasefire. *Int J Gynaecol Obstet* 2011;114:168–73.
59. Bailey PE, van Roosmalen J, Mola G, *et al*. Assisted vaginal delivery in low and middle income countries: an overview. *BJOG: Int J Obstet Gy* 2017;124:1335–44.
60. Wilson A, Truchanowicz EG, Elmoghazy D, *et al*. Symphysiotomy for obstructed labour: a systematic review and meta-analysis. *BJOG: Int J Obstet Gy* 2016;123:1453–61.
61. Bandali S, Thomas C, Hukin E, *et al*. Maternal death surveillance and response systems in driving accountability and influencing change. *Int J Gynaecol Obstet* 2016;135:365–71.
62. Danel I, Graham W, Boerma T. Maternal death surveillance and response. *Bull World Health Organ* 2011;89:779–79A.
63. Viphou N, Brook AJ, Liljestrand J. Clinical indications for cesarean delivery in a Cambodian referral hospital. *Int J Gynaecol Obstet* 2014;124:83–4.
64. Gibbons L, Belizán JM, Lauer JA, *et al*. *The global numbers and costs of additionally needed and unnecessary caesarean sections performed per year: overuse as a barrier to universal coverage. World health report (2010) background paper, 30*. Geneva, Switzerland: WHO, 2010.
65. Betrán AP, Vindevoghel N, Souza JP, *et al*. A systematic review of the Robson classification for caesarean section: what works, doesn't work and how to improve it. *PLoS One* 2014;9:e97769.
66. Robson M, Murphy M, Byrne F. Quality assurance: the 10-Group classification system (Robson classification), induction of labor, and cesarean delivery. *Int J Gynaecol Obstet* 2015;131(Suppl 1):S23–7.
67. Government of Sierra Leone Ministry of Health and Sanitation. *Annual health sector performance report 2016*. Freetown, Sierra Leone: MOHS, 2017.
68. Bertone MP, Wurie H, Samai M, *et al*. The bumpy trajectory of performance-based financing for healthcare in Sierra Leone: agency, structure and frames shaping the policy process. *Global Health* 2018;14:99.