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Impact of surgical infrastructure and personnel on volume and availability of essential surgical procedures in Liberia

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Background: **Essential surgical procedures rank among the most cost-effective of all healthcare interventions. The aim of this study was to enumerate surgical volumes in Liberia, quantify surgical infrastructure, personnel and availability of essential surgical procedures, describe surgical facilities, and assess the influence of human resources and infrastructure on surgical volumes.**

Methods: **An observational countrywide survey was done in Liberia between 20 September and 8 November 2018. All healthcare facilities performing surgical procedures requiring general, regional or local anaesthesia in an operating theatre between September 2017 and August 2018 were eligible for inclusion. Information on facility infrastructure and human resources was collected by interviewing key personnel. Data on surgical volumes were extracted from operating theatre log books.**

Results: **Of 70 healthcare facilities initially identified as possible surgical facilities, 52 confirmed operative capacity and were eligible for inclusion; all but one shared surgical data. A national surgical volume of 462 operations per 100 000 population was estimated. The median hospital offered nine of 26 essential surgical procedures. Unequal distributions of surgical infrastructure, personnel, and essential surgical procedures were identified between facilities. In multivariable regression analysis, surgical human resources ($\beta = 0{\cdot}60$, 95 per cent c.i. 0·34 to 0·87; $P < 0{\cdot}001$) and infrastructure ($\beta = 0{\cdot}03$, 0·02 to 0·04; $P < 0{\cdot}001$) were found to be strongly associated with operative volumes.**

Conclusion: **The availability of essential surgical procedures in Liberia is extremely low. Descriptive tools can quantify inequalities, guide resource allocation, and highlight rational investment areas.**

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Introduction

Essential surgical procedures rank among the most cost-effective of all healthcare interventions[1]. The Disease Control Priorities Project (DCP3) proposed a list of 28 essential surgical procedures as key components of any surgical delivery platform[1]. Investments in district hospitals to improve provision of surgical care have been found to be especially cost-effective[2–5]. A poorly developed surgical system not only precludes delivery of essential healthcare services, but also has direct negative consequences for the economic security and development of individuals, families and nations[6].

A framework of six core surgical indicators has been proposed to monitor progress towards universal access to safe, affordable, surgical and anaesthesia care[6]. Among these indicators is surgical volume, as a means to understand capacities to deliver surgical care[6]. Even though the Global Health Society has increasingly adopted core surgical indicators, comprehensive data at country level are still sparse[7]. Lack of human resources has been highlighted as a main barrier to surgical care[8]. Recent studies[9,10] have

demonstrated human resources to be decisive drivers of surgical volumes. In addition, surgical infrastructure assessments are considered valuable tools in quantifying infrastructural needs[11], although it is not obvious what role infrastructure assessments should play as the relationship between surgical infrastructure and operative volume has been questioned[9]. Facility assessments of surgical capacity, including evaluations of equipment and surgical providers, have recently been highlighted as a leading research priority to decrease perioperative mortality in Africa[12]. There is a need for uniform reporting strategies at country level to describe surgical facilities, guide resource allocation and justify investments.

Liberia, on the coast of West Africa, has some of the worst health statistics worldwide[13]. It is a small nation of 4·3 million inhabitants[14] with a life expectancy of 63 years[15]. The 14-year-long civil war that ended in 2003 and the recent Ebola outbreak have left the health system dysfunctional, with destruction of infrastructure and severe healthcare workforce shortage[13,16–18]. Many medical doctors emigrated, escaped the public sector during the civil war, or died during the Ebola outbreak, leaving the country with only 117 physicians (0·03 per 1000 population)[16]. Two comprehensive studies conducted in 2011 and 2013, both before the Ebola outbreak, identified a critically low density of appropriately trained surgical personnel and infrastructure[19,20].

The health sector relies heavily on external support, as 29 per cent of current healthcare expenditure comes from external sources[13]. Per capita healthcare expenditure is currently US$68 (€57, exchange rate 18 August 2020), compared with US$9869 (€8288) per capita in the USA[15]. The health sector has considerable problems financing the workforce, with 41 per cent of governmental health workers not on the payroll[16]. Surgical services are supposed to be free of charge, but out-of-pocket payments constitute 47 per cent of the total healthcare expenditure, leaving 72 per cent of the population at risk of impoverishing expenditure for surgical care[15].

The aim of this study was to enumerate surgical volumes in Liberia, quantify surgical infrastructure, personnel and availability of essential surgical procedures to describe surgical facilities, and assess the influence of surgical human resources and infrastructure on surgical volumes.

Methods

This was a nationwide observational survey of all healthcare facilities in Liberia performing operative procedures requiring general, regional or local anaesthesia within an operating theatre between September 2017 and August 2018. The Ministry of Health and the Liberian Physician Assistant Association identified healthcare facilities that performed surgery. To detect facilities not registered among the above entities, a snowball sampling technique was used by consulting the County Health Officer team in every county visited.

A team of four data collectors visited all facilities performing surgery between 20 September and 8 November 2018, obtaining data on surgical infrastructure, human resources and surgical volumes. The data-collecting team was composed of a Liberian physician assistant, a Liberian master's student in global health, the president of the Liberian Physician Assistant Association and a Norwegian medical student. The facility administration identified personnel best fitted to provide relevant information. Available human resources in terms of type of position (part-time or full-time) and length of engagement were obtained from structured interviews with both administrative and clinical personnel as verification. Available infrastructure was recorded using the Lancet Commission on Global Surgery Hospital Assessment Tool[6]. Operating theatres were also inspected for confirmation. Operating theatre, delivery and anaesthesia logbooks were all investigated to collect information on surgical volumes. To describe the distribution of operations in different seasons, detailed information was obtained on all operations performed during four preselected months (October 2017, and January, April and July 2018) and entered into Microsoft Excel® 2016 (Microsoft, Redmond, Washington, USA).

Ethical considerations

The Internal Research Board in Liberia granted ethical clearance for this study. The Regional Committee for Medical and Health Research Ethics in central Norway exempted the study from review (number 2018/1008). Facility administrative leaders consented on behalf of their facility to participate in the study, and all facilities included gave consent.

Definitions

Operating theatre activity was defined as the number of operations per theatre per week. Facilities owned by the government were categorized as governmental, whereas all others were listed as private and further subcategorized as either non-profit or for-profit. According to the Liberian Essential Package of Health Services, a hospital was defined as a facility providing 24-h advanced obstetrics and emergency surgical care[21]. A surgical procedure was defined as any procedure requiring general, regional or

local anaesthesia performed within an operating theatre[22]. A surgical procedure was defined as essential if listed under the Essential Surgery Package in the World Bank DCP3[1]. Anyone listed as the main operator for a surgical procedure in the logbook was defined as a surgical provider. Surgical providers were quantified by full-time equivalent (FTE) position according to size (part-time or full-time) and length of their engagement over the study period. Towns with fewer than 50 000 inhabitants were considered rural[23]. In Liberia this meant that all counties except Montserrado county, where Monrovia is located, were considered rural.

Analysis

Annual surgical volumes were calculated by dividing the operation count by population numbers[14]. The distribution of operations was described by multiplying the 4-month sample by three to represent the full study period of 12 months.

Caesarean section rates were calculated as the number of operations performed divided by the estimated number of deliveries. The estimated number of deliveries was calculated by multiplying the crude birth rate with population numbers[24], in line with other studies[25].

Availability of essential surgical procedures was determined at hospital level only, as lower-level facilities are not expected to perform most of these operations. Vacuum extraction/forceps delivery and relief of urinary obstruction were not recorded routinely in theatre logbooks, and were thus excluded from the DCP-defined 28-item essential surgical list for first-level hospitals. The modified 26-item list is presented in *Table S1* (supporting information). All hospitals received an essential surgery availability count ranging from 0 to 26, based on how many of the 26 essential surgical procedures were identified in their theatre logbooks. Because indications for surgery and postoperative diagnoses were not widely available in the logbooks, repair of perforations, bowel obstruction and laparotomy for trauma were all listed as laparotomy.

Hospitals were given a score according to their level of surgical infrastructure, in line with previous studies[7,8]. A total of 32 infrastructure items were selected based on the WHO Guidelines for Essential Trauma Care[26] and the WHO Essential Emergency Equipment List[27]. The infrastructure variables, grouped into five infrastructure categories, are presented in *Table S2* (supporting information). Each variable was scored from 0 to 5, based on availability (0, never available; 1, rarely available; 2, sometimes available; 3, often available; 4, almost always available; 5, always available). Each hospital received a total infrastructure score ranging from 0 (no resources available) to 165 (all resources available all of the time).

FTE positions for all surgical providers were summarized at hospital level. A mixed Poisson regression model with log link function was used to assess the effect of FTE and infrastructure on surgical volume. A random effect of hospital identification was included to account for overdispersion. The hypothesis that FTEs and infrastructure were associated with surgical volume was formulated after the primary data analysis; thus the regression model was a *post hoc* analysis. Only hospitals were included in the regression model. Univariable analysis was undertaken separately for both FTEs and infrastructure. Multivariable analysis with assumed log link function was used to adjust for confounding factors. The multivariable model included FTEs, infrastructure score, presence of surgical residents, number of operating theatres and hospital beds. The co-variables FTEs, theatres and hospital beds were log-transformed in the regression model. The statistical software R version 2.13.1 (R Foundation for Statistical Computing, Vienna, Austria) was used for analysis.

Results

A total of 70 healthcare facilities were initially identified as possible surgical facilities (*Fig. 1*), of which 18 were excluded because no surgery was performed during the study period. All facilities but one consented to share their data.

Fig. 1 Flow diagram of surgical healthcare facilities included in the study

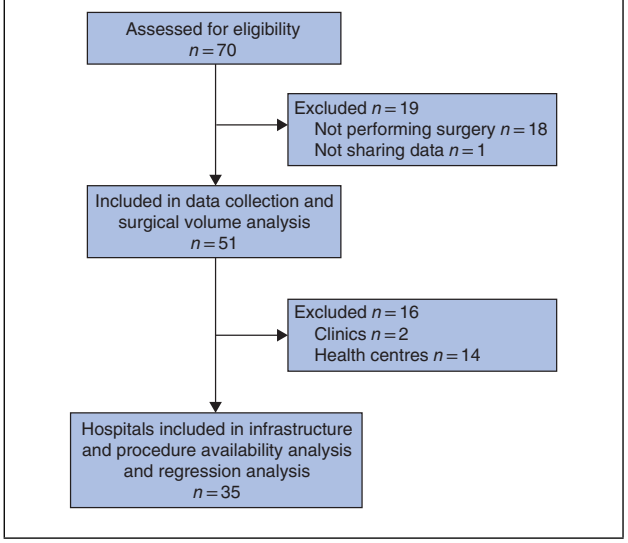
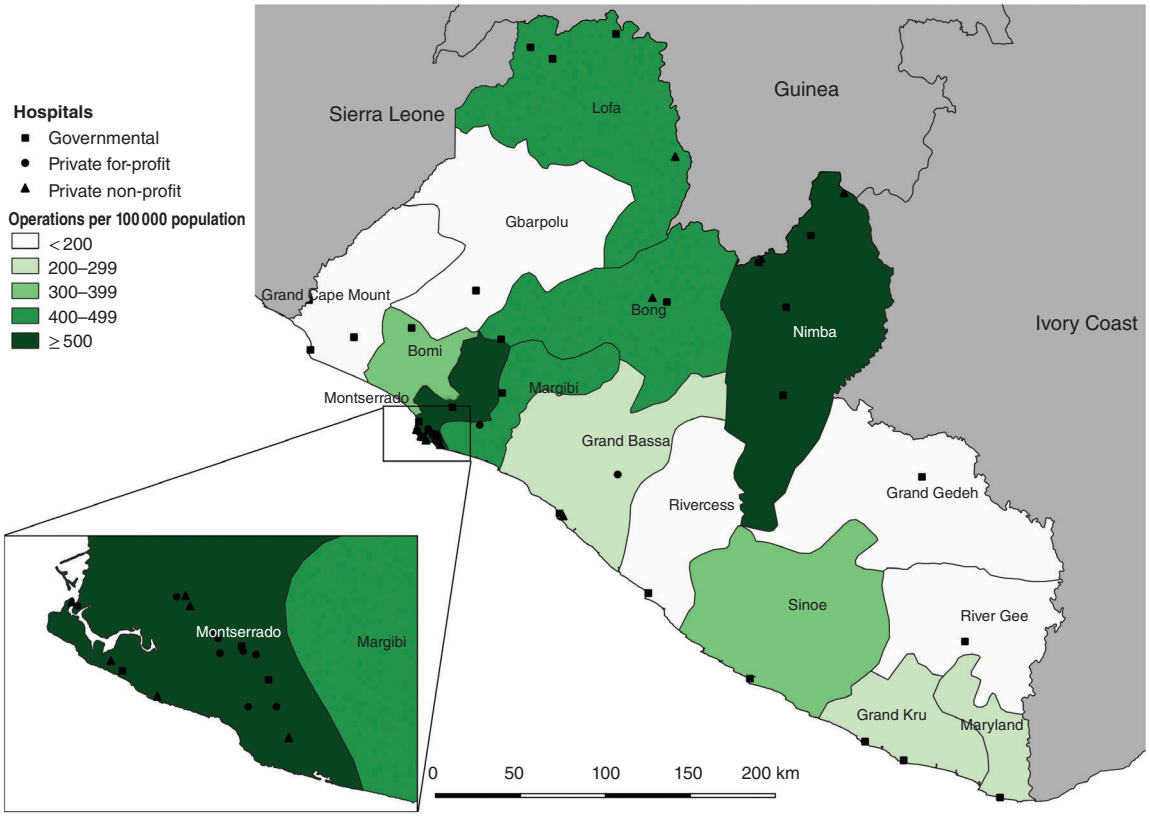


Fig. 2 Surgical volumes and distribution of surgical facilities by county



Annual surgical volume

A total of 19 751 operations, including 7899 caesarean sections, were counted for the full study period. The total operation count gave a national surgical volume of 462 operations per 100 000 population. There was a sevenfold difference in population rates of surgical volume between counties, ranging from 94 to 709 operations per 100 000 population (*Fig. 2*). A total of 6428 surgical procedures, including 2772 caesarean sections, were identified for the four months of October, January, April and July. This extrapolates to 19 284 annually performed surgical procedures and 8316 caesarean sections. Compared with the 12-month count, this gave a 2·4 per cent difference for all operations and a 5·3 per cent difference for caesarean sections.

Distribution of surgical volume

Of the 19 751 operations identified within the study period, 11 910 (60·3 per cent) were performed in governmental facilities, 5925 (30·0 per cent) and 1916 (9·7 per cent) in private non-profit and private for-profit facilities respectively. *Table 1* shows the distribution of operations based on the 4-month sample. The two most commonly performed operations were caesarean section and hernia repair, together responsible for 64·4 per cent (12 411 of 19 284) of the total surgical volume. Obstetrics/gynaecology accounted for 54·4 per cent (10 485 of 19 284) of the total surgical volume, and general surgery and orthopaedics accounted for 39·7 per cent (7665 of 19 284) and 5·9 per cent (1134 of 19 284) of the volume respectively. The national caesarean section rate was 5·4 per cent, ranging from 1·0 to 7·7 per cent across counties.

Essential surgical procedures

Surgical human resources, essential surgery availability, infrastructure and operating theatre activity are presented in *Table 2*. A median of 9·0 of the 26 essential surgical procedures were performed; only one of 12 essential surgical procedures was performed in the injury and orthopaedic category. Of the 21 emergency procedures considered

Table 1 Patient characteristics and distribution of surgical volumes

	Owner			Area		
	Governmental (n = 11 793)	Private non-profit (n = 5676)	Private for-profit (n = 1815)	Urban (n = 8892)	Rural (n = 10 392)	Total (n = 19 284)
Patient age (years)						
≤ 12	519 (4·4)	651 (11·5)	27 (1·5)	684 (7·7)	513 (4·9)	1197 (6·2)
13–17	828 (7·0)	330 (5·8)	81 (4·5)	477 (5·4)	762 (7·3)	1239 (6·4)
≥ 18	9363 (79·4)	4101 (72·3)	1545 (85·1)	6474 (72·8)	8535 (82·1)	15 009 (77·8)
Unknown	1083 (9·2)	594 (10·5)	162 (8·9)	1257 (14·1)	582 (5·6)	1839 (9·5)
Sex						
F	7791 (66·1)	3417 (60·2)	1344 (74·0)	5913 (66·5)	6639 (63·9)	12 552 (65·1)
M	3654 (31·0)	2139 (37·7)	426 (23·5)	2826 (31·8)	3393 (32·7)	6219 (32·2)
Unknown	348 (3·0)	120 (2·1)	45 (2·5)	153 (1·7)	360 (3·5)	513 (2·7)
Obstetrics/gynaecology						
Caesarean section	5538 (47·0)	1866 (32·9)	912 (50·2)	3816 (42·9)	4500 (43·3)	8316 (43·1)
Ectopic pregnancy	240 (2·0)	135 (2·4)	36 (2·0)	192 (2·2)	219 (2·1)	411 (2·1)
Dilatation and curettage*	192 (1·6)	252 (4·4)	102 (5·6)	324 (3·6)	222 (2·1)	546 (2·8)
Hysterectomy	195 (1·7)	144 (2·5)	45 (2·5)	180 (2·0)	204 (2·0)	384 (2·0)
Tubal ligation	18 (0·2)	0 (0)	0 (0)	0 (0)	18 (0·2)	18 (0·1)
Vasectomy	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cryotherapy for cervical lesions	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Other procedure†	510 (4·3)	198 (3·5)	102 (5·6)	420 (4·7)	390 (3·8)	810 (4·2)
General surgery						
Hernia surgery	2826 (24·0)	1002 (17·7)	267 (14·7)	1320 (14·8)	2775 (26·7)	4095 (21·2)
Laparotomy	471 (4·0)	294 (5·2)	24 (1·3)	411 (4·6)	378 (3·6)	789 (4·1)
Appendicectomy	183 (1·6)	162 (2·9)	96 (5·3)	228 (2·6)	213 (2·0)	441 (2·3)
Hydrocelectomy	153 (1·3)	21 (0·4)	24 (1·3)	39 (0·4)	159 (1·5)	198 (1·0)
Colostomy	24 (0·2)	9 (0·2)	0 (0)	30 (0·3)	3 (0·0)	33 (0·2)
Gallbladder surgery	6 (0·1)	0 (0)	0 (0)	0 (0)	6 (0·1)	6 (0·0)
Other procedure‡	927 (7·9)	1065 (18·8)	111 (6·1)	1161 (13·1)	942 (9·1)	2103 (10·9)
Injury						
Wound debridement	150 (1·3)	117 (2·1)	12 (0·7)	165 (1·9)	114 (1·1)	279 (1·4)
Fracture reduction	54 (0·5)	72 (1·3)	12 (0·7)	120 (1·3)	18 (0·2)	138 (0·7)
Amputation	63 (0·5)	60 (1·1)	3 (0·2)	81 (0·9)	45 (0·4)	126 (0·7)
Skin grafting	33 (0·3)	30 (0·5)	0 (0)	57 (0·6)	6 (0·1)	63 (0·3)
External fixation	30 (0·3)	12 (0·2)	0 (0)	42 (0·5)	0 (0)	42 (0·2)
Tube thoracostomy	9 (0·1)	30 (0·5)	0 (0)	21 (0·2)	18 (0·2)	39 (0·2)
Escharotomy/fasciotomy	3 (0·0)	6 (0·1)	0 (0)	6 (0·1)	3 (0·0)	9 (0·0)
Burrhole	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Surgical airway	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Other procedure	66 (0·6)	72 (1·3)	9 (0·5)	99 (1·1)	48 (0·5)	147 (0·8)
Non-trauma orthopaedics						
Debridement of osteomyelitis	48 (0·4)	81 (1·4)	3 (0·2)	84 (0·9)	48 (0·5)	132 (0·7)
Drainage of septic arthritis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Unknown procedure	54 (0·5)	48 (0·8)	57 (3·1)	96 (1·1)	63 (0·6)	159 (0·8)

Values in parentheses are percentages. *Includes manual vacuum aspiration; †includes repair of cervical, vaginal or perineal tear, cystectomy and myomectomy; ‡includes male circumcision, cleaning and dressing, excision of lipoma, drainage of abscess, orchidectomy, secondary closure and wound suturing.

Table 2 Availability of essential surgical procedures, surgical providers and infrastructure at hospital level

	Owner			Area		
	Governmental	Private non-profit	Private for-profit	Urban	Rural	Total
Surgical providers						
Total surgical provider FTE†	149·2	46·5	12·8	90·9	117·6	208·5
Surgical activity						
No. of operating theatres	39	14	10	19	44	63
Operating theatre activity‡	5·7	7·6	2·1	7·7	4·6	5·6
Surgical provider FTE per operating theatre	3·8	3·3	1·3	4·8	2·7	3·3
Availability of essential surgery*						
Obstetrics/gynaecology (7 procedures)	2·5 (2·0–4·0)	3·5 (1·5–4·0)	2·0 (1·0–3·0)	4·0 (2·0–4·0)	2·0 (2·0–3·0)	3·0 (2·0–4·0)
General surgery (7 procedures)	5·0 (3·0–5·0)	4·5 (3·3–5·8)	2·0 (0·5–4·5)	5·0 (3·0–6·0)	4·0 (3·0–5·0)	4·0 (3·0–5·0)
Injury and orthopaedics (12 procedures)	1·0 (1·0–2·0)	4·0 (3·0–7·5)	1·0 (0·5–3·0)	3·0 (1·0–8·0)	1·0 (1·0–3·0)	1·0 (1·0–3·0)
Emergency operations (21 procedures)	8·0 (6·0–9·0)	11·0 (7·8–14·5)	6·0 (2·0–9·0)	9·0 (7·0–15·5)	8·0 (5·5–10·0)	8·0 (6·0–11·0)
All procedures (26 procedures)	9·0 (6·8–10·0)	12·0 (8·5–16·8)	7·0 (2·0–9·5)	10·0 (7·0–18·0)	9·0 (5·8–10·3)	9·0 (7·0–12·0)
Infrastructure score*						
Anaesthesia (range 0–60)	55·0 (46·5–59·3)	60·0 (45·3–60·0)	37·0 (32·5–56·5)	60·0 (57·0–60·0)	49·5 (43·5–56·8)	55·0 (45·0–60·0)
Theatre equipment and sterility (range 0–45)	45·0 (42·5–45·0)	45·0 (45·0–45·0)	45·0 (44·0–45·0)	45·0 (45·0–45·0)	45·0 (43·0–45·0)	45·0 (43·0–45·0)
Personnel safety (range 0–20)	20·0 (20·0–20·0)	20·0 (20·0–20·0)	20·0 (20·0–20·0)	20·0 (20·0–20·0)	20·0 (20·0–20·0)	20·0 (20·0–20·0)
Patient monitoring (range 0–25)	25·0 (22·8–25·0)	25·0 (22·8–25·0)	25·0 (20·5–25·0)	24·0 (22·0–25·0)	25·0 (24·0–25·0)	25·0 (23·0–25·0)
Injury (range 0–15)	7·5 (5·0–10·3)	13·5 (6·0–15·0)	14·0 (10·0–15·0)	14·0 (10·5–15·0)	8·5 (5·0–11·3)	10·0 (5·0–15·0)
Total (range 0–165)	148·0 (139·0–157·8)	158·0 (142·0–165·0)	138·0 (128·5–161·5)	157·0 (153·0–163·0)	146·0 (132·3–158·3)	149·0 (138·0–160·0)
Hospital infrastructure						
No. of hospitals	22	8	5	9	26	35
Uses safe surgery checklist	14	6	2	6	16	22
Has blood bank service available	18	8	4	9	21	30
Needs generator for electricity	20	7	4	8	23	31
Has running water available§	19	7	5	9	22	31
Has functional CT machine	1	0	0	0	1	1
Has postanaesthesia care unit	9	3	3	5	10	15
Has ICU	8	3	1	2	10	12
Has functional anaesthesia machine	15	5	2	6	16	22
Has functional ventilator machine§	11	5	1	5	12	17
Has oxygen available	15	6	3	8	16	24

*Values are median (i.q.r.). †Full-time equivalent (FTE) position (one full-time position for 1 year = 1 FTE). ‡Number of operations performed per operating theatre per week. §One missing value.

especially important to be available widely geographically, only eight were available among rural hospitals. Urban hospitals had a higher availability of essential surgical procedures, regardless of category. The private non-profit sector performed 12 of 26 essential procedures, compared with nine in the governmental sector and seven in the private for-profit sector.

Human resources and infrastructure

A total of 143 interviews were undertaken to collect information on surgical personnel and infrastructure. A total of 208·5 surgical provider FTEs were recorded in all of the surgical hospitals. The private for-profit sector had the fewest surgical providers per operating theatre,

Table 3 Regression model assessing influence of surgical human resources (full-time equivalents) and infrastructure on annual surgical volumes

		Univariable model		Multivariable model	
	Median*	Coefficient†	*P*	Coefficient†	*P*
Surgical human resources (FTE)	3·6 (2·0–7·6)	0·98 (0·68, 1·29)	< 0·001	0·60 (0·34, 0·87)	< 0·001
Infrastructure score	149 (138–160)	0·05 (0·03, 0·07)	< 0·001	0·03 (0·02, 0·04)	< 0·001

Values in parentheses are *i.q.r. and †95 per cent confidence intervals. FTE, full-time equivalent.

almost three times less than in governmental and private non-profit theatres. Nationally, 5·6 operations were performed per theatre per week. The private non-profit hospitals had the most productive operating theatres by owner category, with 3·6 times the activity of private for-profit theatres. By area, urban operating theatres had almost twice the activity of rural theatres.

Anaesthesia and injury infrastructure categories were the most deficient in all hospitals surveyed. Private non-profit hospitals were better equipped (infrastructure score 158 of 165) than governmental and private for-profit hospitals (148 and 138 of 165 respectively) (*Table 2*). About two-thirds of the hospitals reported using a safe surgery checklist during surgery. Most had a blood bank service available; all hospitals in urban areas had access to blood bank services, compared with rural areas where five of 26 did not have access. Oxygen supplies were always available at 24 of 35 hospitals nationally. Many hospitals had no dedicated postanaesthesia care unit or ICU. At the time of the data collection, there was only one functional CT scanner in the country. No hospital had a functional MR machine.

Association between infrastructure, human resources and surgical volume

The mixed Poisson regression model revealed a strong association between both FTEs and infrastructure score and surgical volume in univariable analysis (*Table 3*). The multivariable regression model showed the same trend.

Discussion

This study found a national surgical volume of 462 operations per 100 000 population in Liberia. Hospitals offered a median of 9·0 of 26 essential surgical procedures described by the World Bank DCP3. Quantitative tools identified unequal distribution of surgical infrastructure, personnel, and availability of essential surgical procedures between facilities. A clear positive association was found between surgical human resources, infrastructure and surgical volume.

The surgical volumes found in this study were at the lower end of previously published data[28]. A clear correlation between increased life expectancy and increased surgical rates up to 1533 operations per 100 000 population has been reported[29], and The Lancet Commission on Global Surgery[6] has set a target of 5000 operations per 100 000 population for all countries by 2030. The national surgical volume of 462 operations per 100 000 population was higher than seen in 2013, when operative rates were 330 per 100 000 population[19].

A sevenfold difference in surgical volume between counties indicated considerable inequity in surgical service provision. The rural population had almost no access to treatment for injury. As the disease burden from injuries and other surgical conditions has been predicted to increase in the future[6], these numbers should be a strong call for action. Improved availability of essential surgical care should be implemented early in the path to universal healthcare coverage[1], and has been considered an investment rather than a cost[30].

A study[20] investigating 16 county hospitals in Liberia in 2008 identified uniform, gross deficiencies in infrastructure, supplies and equipment. Of these, 15 hospitals met the inclusion criteria for the present study. Over the past decade, the number of these 15 hospitals with full-time access to oxygen supplies increased from five to eight, full-time access to running water increased from three to eight (one missing value), the presence of a functioning anaesthesia machine increased from three to ten, and the presence of a postoperative recovery room increased from three to six. The regression model revealed an association between infrastructure and surgical volume, and it is likely that infrastructural progress has influenced surgical capacity.

Previous studies[10,31] have concluded that reporting both the volume and distribution of surgical procedures is essential in facilitating targeted intervention to strengthen surgical capacity. It has been suggested[32] that future global surgery benchmarking should consider both total operative numbers and priority levels for operative procedures. There is no uniform reporting system for distribution

and availability of operations at global level. In Liberia, the present study found low availability of several essential operations. This finding can guide a more targeted strengthening as it allows national authorities to compare surgical facilities and highlights poorly developed disciplines. Availability of essential surgery gives a more comprehensive picture of operative volume distribution, and can be used as a compliementary method for reporting surgical volumes.

Providing detailed information on infrastructure and workforce can highlight areas of improvement. The present study demonstrated large differences in operating theatre use between sectors and geographical regions. Facilities with low theatre activity can learn from facilities with higher activity, and this can be a low-cost strategy for improvement. Another striking aspect was the low availability of surgical personnel, which was closely linked with surgical volumes in the regression analysis. Surgical human resources have also been identified as key drivers of surgical volumes in Ghana and Uganda[9,10]. Expansion of the surgical workforce through task-sharing to non-specialists has been applied in many low-income settings[33], and may be a strategy for bridging the gap to higher operative volumes[6]. Task-sharing has also been found to increase retention of surgical personnel in rural areas[34]. The introduction of a surgical task-sharing programme rapidly and safely increased surgical volumes in Liberia's neighbour, Sierra Leone[35]. As the two surgical procedures, caesarean section and hernia repair, constitute almost two-thirds of the total surgical volume, task-sharing seems like a rational strategy that may allow more specialized physicians to offer a broader range of surgical procedures. Specialized physicians can work to increase the number of essential surgical procedures offered, as this study has highlighted an absence of several critical operations, especially trauma.

This study has limitations. Data were collected from records where completeness and accuracy can be problematic, although surgical providers self-recording in operating theatre logbooks have been found to be accurate for assessing surgical volumes in low-resource settings[36]. The distribution of operations relied on a 4-month sample from the theatre logbooks. Even though the collected sample multiplied by three correlated well with the actual annual count for both total volume of procedures performed and for caesarean section in particular, there is a risk that some seasonal variations were missed. Some essential surgical procedures on the modified list may have been performed outside the operating theatre and therefore not registered in the theatre logbook. Most procedures on the list would, however, require a high degree of infrastructure, including aseptic environment and sterile equipment, so the numbers are likely to have been small.

This study has demonstrated a low availability of essential surgical procedures in Liberia. There is an urgent need to scale up surgical services, and strategies to do this should be explored. Investments in surgical human resources and infrastructure are important strategies with high potential impact. Quantitative tools providing detailed information on surgical infrastructure, personnel, and availability of essential surgical procedures across various sectors and geographical regions can allow national authorities to allocate resources, invest rationally, and address the underlying cause of low surgical volumes. These tools can also be used to track and review developmental strategies. The World Bank DCP3 offers a framework for surgical procedure categorization that can aid capacity strengthening. This framework is easy applicable and can be used to describe the availability of the most cost-effective surgeries. This gives added value when reported together with surgical volumes, as it provides more detailed information on where to allocate resources within the surgical system.

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Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.