ORIGINAL CLINICAL RESEARCH REPORT

# An Assessment of Anesthesia Capacity in Liberia: Opportunities for Rebuilding Post-Ebola

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**BACKGROUND:** The health system of Liberia, a low-income country in West Africa, was devastated by a civil war lasting from 1989 to 2003. Gains made in the post-war period were compromised by the 2014–2016 Ebola epidemic. The already fragile health system experienced worsening of health indicators, including an estimated 111% increase in the country's maternal mortality rate post-Ebola. Access to safe surgery is necessary for improvement of these metrics, yet data on surgical and anesthesia capacity in Liberia post-Ebola are sparse. The aim of this study was to describe anesthesia capacity in Liberia post-Ebola as part of the development of a National Surgical, Obstetric, and Anesthesia Plan (NSOAP).

**METHODS:** Using the World Federation of Societies of Anaesthesiologists (WFSA) Anaesthesia Facility Assessment Tool (AFAT), we conducted a cross-sectional survey of 26 of 32 Ministry of Health recognized hospitals that provide surgical care in Liberia. The surveyed hospitals served approximately 90% of the Liberian population. This assessment surveyed infrastructure, workforce, service delivery, information management, medications, and equipment and was performed between July and September 2019. Researchers obtained data from interviews with anesthesia department heads, medical directors and through direct site visits where possible.

**RESULTS:** Anesthesiologist and nurse anesthetist workforce densities were 0.02 and 1.56 per 100,000 population, respectively, compared to 0.63 surgeons per 100,000 population and 0.52 obstetricians/gynecologists per 100,000 population. On average, there were 2 functioning operating rooms (ORs; OR in working condition that can be used for patient care) per hospital (standard deviation [SD] = 0.79; range, 1–3). Half of the hospitals surveyed had a postanesthesia care unit (PACU) and intensive care unit (ICU); however, only 1 hospital had mechanical ventilation capacity in the ICU. Ketamine and lidocaine were widely available. Intravenous (IV) morphine was always available in only 6 hospitals. None of the hospitals surveyed completely met the minimum World Health Organization (WHO)-WFSA standards for health care facilities where surgery and anesthesia are provided.

**CONCLUSIONS:** Overall, we noted several critical gaps in anesthesia and surgical capacity in Liberia, in spite of the massive global response post-Ebola directed toward health system development. Further investment across all domains is necessary to attain minimum international standards and to facilitate the provision of safe surgery and anesthesia in Liberia. The study results will be considered in development of an NSOAP for Liberia. (Anesth Analg XXX;XXX:00–00)

## KEY POINTS

- **Question:** What is the current baseline anesthesia capacity in Liberia post-Ebola?
- **Findings:** Anesthesia capacity in Liberian hospitals does not meet minimum international standards, with critical shortages across domains.
- **Meaning:** Despite the massive global response directed at health system development post-Ebola, anesthesia capacity has remained stagnant in Liberia and warrants further resource allocation.

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## GLOSSARY

**AFAT** = Anaesthesia Facility Assessment Tool; **Airway Devices** = oropharyngeal airways, laryngoscopes, and endotracheal tubes; **Anesthesia Workforce** = includes anesthesiologists and nurse anesthetists; **BP** = blood pressure; **Functioning operating room** = term used in WFSA AFAT. Defined as operating room in working condition that can be used for patient care; **HR** = heart rate; **ICU** = intensive care unit; **IM** = intramuscular; **IQR** = interquartile range; **IRB** = institutional review board; **IV** = intravenous; **LCoGS** = Lancet Commission on Global Surgery; **LCPS** = Liberian College of Physicians and Surgeons; **LIC** = low-income countries; **LMIC** = low- and middle-income countries; **MOH** = Ministry of Health; **MSF** = Médecins Sans Frontières; **NIBP** = noninvasive blood pressure; **NPAP** = nonphysician anesthesia provider; **NSAIDS** = nonsteroidal anti-inflammatory drugs; **NSOAP** = National Surgical, Obstetric, and Anesthesia Plan; **OR** = operating room; **PACU** = postanesthesia care unit; **PAP** = physician anesthesia provider; **POMR** = perioperative mortality rate; **REDCap** = Research Electronic Data Capture; **SAO** = surgeon, anesthesiologist, and obstetrician; **SAO provider** = term used by Lancet Commission on Global surgery to describe the specialist surgical physician workforce (includes surgeons, anesthesiologists, and obstetricians). Excludes nurse anesthetists; **SD** = standard deviation; **SQ** = subcutaneous; **WFSA** = World Federation of Societies of Anaesthesiologists; **WHO** = World Health Organization

The 2015 Lancet Commission on Global Surgery (LCoGS) revealed glaring disparities in availability of safe surgery and anesthesia care globally.[1] Weak health care systems and relative neglect of surgery on the global health agenda have resulted in 5 billion people worldwide without access to safe, affordable surgery, and anesthesia.[1–3] This is worsened by the ongoing epidemiological transition in low- and middle-income countries (LMICs), which has led to an increased burden of disease requiring surgical care from cancer, road traffic injuries, and cardiovascular disease.[1,4,5] It is projected that 143 million additional procedures are required yearly in LMICs to reduce disability and premature death from surgical disease.[1] To address this need by 2030, some of the LCoGS recommendations for countries include a surgeon, anesthesiologist, and obstetrician (SAO) density of 20 per 100,000 population, a minimum of 5000 surgical procedures per 100,000 population and 100% perioperative mortality rate (POMR) tracking. Shortages in workforce, infrastructure, and medications for safe anesthesia and surgery remain a key barrier in achieving these targets and ultimately improving surgical outcomes in LMICs.[5–9]

In Liberia, a low-income West African country with a population of 4.6 million[10] (of whom 50.9% live below the national poverty line[11]), these shortages were exacerbated by the 2014–2016 Ebola epidemic, which erased gains made in the period after the civil war (1989–2003). About 8% of Liberian doctors, nurses, and midwives died during the epidemic.[12] This loss, coupled with other factors, contributed to worsened health outcomes as evidenced by an estimated 111% increase in maternal mortality post-Ebola.[12] In response,[13] the Government of Liberia has embarked on a robust national health rebuilding plan and has identified anesthesia as a critical component in achieving health care improvement goals.

Surgical capacity assessments conducted in Liberia before the Ebola epidemic were limited in scope, focusing on a small percentage of hospitals and not specifically on anesthesia care.[14,15] Additionally, the World Health Organization (WHO) Tool for Situational Analysis to Assess Emergency and Essential Surgical Care, used in a previous assessment done in 2008, may have poor reliability when evaluating processes of care.[16] Given the disruption of service delivery and development caused by the Ebola epidemic, a better understanding of current anesthesia capacity in Liberia is warranted to inform future National Surgical, Obstetric, and Anesthesia Plan (NSOAP). Using the more comprehensive tool developed by the World Federation of Societies of Anaesthesiologists (WFSA), this study aims to establish a new baseline for anesthesia capacity in Liberia post-Ebola.

## METHODS

We obtained ethics approval for this study from the University of Liberia-Pacific Institute for Research and Evaluation Institutional Review Board (#19-02-154 UL-PIRE IRB; Monrovia, Liberia) and the Vanderbilt University Medical Center Institutional Review Board (#190412 IRB; Nashville, TN). Interviewers obtained written informed consent from all participants.

### Data Collection Tool

We utilized the WFSA Anaesthesia Facility Assessment Tool (AFAT), a comprehensive survey created specifically to evaluate anesthesia capacity, for this study. The questions included in the survey address key recommendations outlined in the 2018 WHO-WFSA International Standards for Safe Practice of Anesthesia.[17] The recommendations are stratified into 3 levels based on facility size and surgical capacity, including highly recommended (minimum expected standards), recommended, and suggested.[17] While it shares similarities with surgical capacity assessment tools used in other settings,[18–20] the AFAT contains a greater focus on anesthesia-specific resources.[21,22]

The tool consists of 200 items divided into categories, including facility characteristics, infrastructure, blood product services, information management, workforce, service delivery, surgical logbook, medications, and equipment. It employs frequency grouping labels using the terms "always" (100% of the time), "almost always" (76%–99%), "often" (51%–75%), "sometimes" (26%–51%), "rarely" (1%–25%), and "never" (0% of the time). The tool is publicly available on the WFSA Website (https://www.wfsahq.org/resources/anaesthesia-facility-assessment-tool).

### Study Setting and Site Selection

Liberia has a tiered national health system with 3 main levels of care: primary, secondary, and tertiary.[23] The primary level consists of small health centers that provide basic care and community health services. The secondary level encompasses large health centers and county referral hospitals. The tertiary level includes regional referral hospitals and the national referral hospital (John F Kennedy Medical Center). These correspond to WHO levels 1, 2, and 3, respectively. County referral hospitals and tertiary level hospitals provide the majority of surgical and anesthesia care in Liberia.

For the purpose of this study, we identified all Ministry of Health (MOH) recognized facilities providing surgical care at the county level and above (n = 32). We included 26 of these in the capacity assessment. In most Liberian hospitals, anesthesia department heads serve as directors of operating room (OR) services and were therefore best suited to answer the survey questions. We excluded 5 facilities from the study because they did not have any currently practicing anesthesia providers, and it was reported that no surgery was being performed in these facilities. These excluded hospitals are located in Grand Kru and Sinoe counties, as well as 2 of the 4 hospitals in Lofa county (n = 4). The sole nurse anesthetist in River Gee county was on extended sick leave, so we excluded this hospital, as well. We also excluded the Médecins Sans Frontières Hospital (MSF) in Monrovia from the study as it was thought not to be representative of Liberia's anesthesia infrastructure. The excluded hospitals (with the exception of the MSF facility) serve a combined population of 416,016 people (roughly 10% of total population of Liberia) based on World Bank 2016 population estimates and national census data on catchment populations.[10,24]

### Data Collection

Researchers collected data for the capacity assessment between July 2019 and September 2019. We contacted hospital directors and/or department heads of anesthesia at study sites by telephone, requested their consent for the study, and fixed assessment dates. The study dates coincided with the rainy season in Liberia; thus, roads to some counties were not traversable. One of the authors (D.S.O.) performed site visits where possible (n = 14; 54% of assessments) and conducted interviews with the department heads of anesthesia (supplemented with information from other personnel such as medical directors and hospital administrators). Researchers collected data on surgical volume and perioperative mortality from operative logbooks, where available. To account for potential double-counting of individuals who work in multiple hospitals, we used a directory of active anesthetists obtained from the national professional anesthesia society to complement the workforce data. The AFAT provided data on the number of SAO providers and we calculated SAO provider density, OR density, and annual surgical volume using World Bank 2016 estimates for total and county populations.[10]

### Statistical Analysis

We entered data from paper forms into a WFSA Research Electronic Data Capture (REDCap) database managed by the University of California, San Francisco and exported into EXCEL Version 16.9 (181109). We calculated descriptive statistics for the closed-ended questions, reported the categorical variables as frequencies and percentages and the continuous variables as means (standard deviation [SD]) or medians (interquartile range [IQR]).

## RESULTS

### Overview

We surveyed a total of 26 hospitals, representing 81% of Liberian MOH recognized facilities providing surgical care, and serving approximately 90% of the Liberian population, based on catchment populations.[10,24] Fourteen of these surveys were on-site assessments (54%). For the remaining surveys, we conducted 4 assessments by telephone (15%), and 8 in-person with anesthesia department heads in the capital city, Monrovia (31%). Basic demographics for each facility surveyed are presented in Table 1. The majority (n = 17; 65%) of the hospitals surveyed are public.

Half (13 of 26) of the hospitals included in this assessment are WHO level 2 facilities, and the other half are WHO level 3 facilities, based on treatment and procedure capabilities.

### Infrastructure

In terms of basic infrastructure, about half of the hospitals did not have constant access to running water (43%) and oxygen (55%). Nearly 70% did not always have access to electricity, as shown in Table 2. Oxygen cylinders, supplemented by portable oxygen concentrators, served as the main oxygen source. Only 4 of

**Table 1. Basic Metrics of 26 Hospitals Surveyed Using the WFSA Anaesthesia Facility Assessment Tool**

| County | Hospital | No. of inpatient beds | No. of available ORs (no. of functioning ORs) |
|---|---|---|---|
| Bomi | Liberia Government Hospital (Bomi) | 50–99 | 2 (1) |
| Bong | Bong Mines Hospital | 50–99 | 3 (1) |
| | Charles B Dunbar Hospital | 50–99 | 2 (2) |
| | Phebe Hospital | 100–299 | 2 (2) |
| Gbarpolu | Chief Jallahlon Medical Center | 50–99 | 1 (1) |
| Grand Bassa | Liberia Agriculture Company Hospital | 100–299 | 1 (1) |
| | Liberia Government Hospital (Buchanan) | 50–99 | 2 (1) |
| Grand Cape Mount | St. Timothy's Hospital | 50–99 | 1 (1) |
| Grand Gedeh | Martha Tubman Memorial Hospital | 100–299 | 2 (2) |
| Lofa | Kolahun Hospital | 100–299 | 1 (1) |
| | Tellewoyan Memorial Hospital | 100–299 | 3 (3) |
| Margibi | CH Rennie Hospital | <50 | 2 (1) |
| | Du-side Hospital | 100–299 | 3 (3) |
| Maryland | JJ Dossen Hospital[a] | | 2 (2) |
| Montserrado | Benson Hospital | 50–99 | 2 (1) |
| | Bensonville Hospital | 50–99 | 1 (1) |
| | ELWA Hospital | 50–99 | 3 (3) |
| | James N David Memorial Hospital | 50–99 | 2 (1) |
| | John F. Kennedy Medical Center (National Referral Hospital) | 300–499 | 8 (3) |
| | Redemption Hospital | 100–299 | 2 (2) |
| | Seventh-day Adventist Cooper Memorial Hospital | 50–99 | 2 (1) |
| | St. Joseph's Catholic Hospital | 50–99 | 3 (3) |
| Nimba | Arcelor Mittal | 50–99 | 2 (2) |
| | Ganta United Methodist | 100–299 | 2 (2) |
| | Jackson F Doe Memorial Hospital | 100–299 | 2 (2) |
| River Cess | St. Francis Hospital | 100–299 | 1 (1) |

Abbreviations: OR, operating room; WFSA, World Federation of Societies of Anaesthesiologists.
[a]Missing data.

**Table 2. Availability of "Highly Recommended"[a] Infrastructure Reported by 26 Facilities Surveyed in Liberia**

| | Always[b] n (%)[c] | Almost always[b] n (%)[c] | Often[b] n (%)[c] | Sometimes[b] n (%)[c] | Rarely[b] n (%)[c] | Never[b] n (%)[c] |
|---|---|---|---|---|---|---|
| Basic infrastructure (n = 26) | | | | | | |
| Oxygen available | 12 (46) | 8 (31) | 3 (12) | 3 (12) | 0 (0) | 0 (0) |
| Running water available | 15 (58) | 7 (27) | 1 (4) | 3 (12) | 0 (0) | 0 (0) |
| Electricity available | 8 (31) | 11 (42) | 2 (8) | 4 (15) | 1 (4) | 0 (0) |
| Operational power generator[d] (n = 24) | 10 (42) | 8 (33) | 2 (8) | 4 (17) | 0 (0) | 0 (0) |
| Adequate operating theater lighting[d] (n = 24) | 16 (67) | 3 (13) | 1 (4) | 4 (17) | 0 (0) | 0 (0) |
| Tilting operating table[d] (n = 24) | 15 (63) | 6 (25) | 0 (0) | 2 (8) | 0 (0) | 1 (4) |
| $O_2$ supply | | | | | | |
| Portable oxygen concentrator | 16 (62) | 2 (8) | 4 (15) | 0 (0) | 1 (4) | 3 (1) |
| Oxygen cylinders with tubing | 15 (58) | 2 (8) | 1 (4) | 2 (8) | 1 (4) | 5 (19) |
| Central oxygen generation plant | 4 (15) | 1 (4) | 0 (0) | 1 (4) | 0 (0) | 20 (77) |

Abbreviations: WFSA, World Federation of Societies of Anaesthesiologists; WHO, World Health Organization.
[a]Highly recommended per WHO-WFSA International Standards for Safe Anesthesia Care.
[b]Always (100% of the time), almost always (76%–99% of the time), often (51%–75% of the time), sometimes (26%–51% of the time), rarely (1%–25% of the time), never (0% of the time).
[c]Percentages have been rounded and may not add up to 100.
[d]Missing data.

the 26 hospitals surveyed had a functioning central oxygen generation plant that was always available (15%). On average, there were 2 functioning ORs per hospital (SD = 0.79; range, 1–3). The total number of ORs for all hospitals surveyed was 57; however, the total number of functioning ORs was 44. This equates to a functioning OR density of 0.95 per 100,000 population. Roughly half (n = 15; 58%) of the hospitals had a postanesthesia care unit (PACU), with the number of beds in each PACU ranging from 2 to 8. Half (13 of 26) of the sampled hospitals had a dedicated intensive care unit (ICU). Of these, only 1 hospital had an ICU equipped with mechanical ventilation.

## Blood Product Services

All hospitals included in this assessment performed blood transfusions and all but 2 reported type and crossmatch capacity. Most facilities (22 of 26) reported that patient family donors were the primary source of blood; however, 2 facilities used paid donors as

**Table 3. Number of SAO Providers Reported by 26 Hospitals Surveyed Using the WFSA Anaesthesia Facility Assessment Tool**

| County | Hospital | Surgeons | Anesthesiologists | Obstetrician/gynecologists |
|---|---|---|---|---|
| Bomi | Liberia Government Hospital (Bomi) | 0 | 0 | 0 |
| Bong | Bong Mines Hospital | 0 | 0 | 0 |
| | Charles B Dunbar Hospital | 0 | 0 | 2 |
| | Phebe Hospital | 2 | 0 | 2 |
| Gbarpolu | Chief Jallahlon Medical Center | 0 | 0 | 0 |
| Grand Bassa | Liberia Agriculture Company Hospital | 0 | 0 | 0 |
| | Liberia Government Hospital (Buchanan) | 0 | 0 | 1 |
| Grand Cape Mount | St. Timothy's Hospital | 0 | 0 | 0 |
| Grand Gedeh | Martha Tubman Memorial Hospital | 0 | 0 | 1 |
| Lofa | Kolahun Hospital | 0 | 0 | 0 |
| | Tellewoyan Memorial Hospital | 1 | 0 | 1 |
| Margibi | CH Rennie Hospital | 1 | 0 | 1 |
| | Du-side Hospital | 0 | 0 | 0 |
| Maryland | JJ Dossen Hospital | 1 | 0 | 1 |
| Montserrado | Benson Hospital | 0 | 0 | 1 |
| | Bensonville Hospital | 0 | 0 | 0 |
| | ELWA Hospital | 2 | 0 | 1 |
| | James N David Memorial Hospital | 0 | 0 | 0 |
| | John F. Kennedy Medical Center (National Referral Hospital) | 10 | 0 | 5 |
| | Redemption Hospital | 4 | 0 | 3 |
| | Seventh-day Adventist Cooper Memorial Hospital | 1 | 0 | 0 |
| | St. Joseph's Catholic Hospital | 2 | 0 | 2 |
| Nimba | Arcelor Mittal | 0 | 0 | 0 |
| | Ganta United Methodist | 2 | 0 | 0 |
| | Jackson F Doe Memorial Hospital | 3 | 1 | 2 |
| River Cess | St. Francis Hospital | 0 | 0 | 1 |
| Total | | 29 | 1 | 24 |

Abbreviations: SAO, surgeon, anesthesiologist, and obstetrician; WFSA, World Federation of Societies of Anaesthesiologists.

their main source. Whole blood is the most commonly transfused, and only 2 facilities had access to separated blood components (including plasma, platelets, and packed red blood cells). In nearly half of the hospitals surveyed, it takes between 1 and 5 hours to obtain red blood cells in an emergency. The longest reported time was 10–24 hours, by 1 facility.

## Information Management

Most hospitals (n = 17; 65%) surveyed used solely paper patient charts for record keeping. No facility used electronic charts exclusively. A few reported using both paper and electronic charts. Patient charts were always accessible across multiple visits in 42% of the facilities. In terms of intraoperative record keeping, most facilities reported consistent documentation of surgical cases in logbook (n = 25; 96%), and also documentation of anesthetic details in patient charts (n = 21; 85%). Only 1 hospital reported consistent access to Internet provided by the facility administration.

## Workforce

The anesthesia workforce density for the entire country is 1.58 per 100,000 population, consisting of 72 nurse anesthetists and 1 anesthesiologist. This amounts to anesthesiologist and nurse anesthetist workforce densities of 0.02 and 1.56 per 100,000 population, respectively. There were 29 surgeons, 24 obstetricians/gynecologists, and 1 anesthesiologist working in the hospitals surveyed, equating to a total of 54 SAO physicians (Table 3) and a SAO provider density of 1.25 per 100,000 population for 12 of 15 counties. The highest reported SAO density was 2.16 per 100,000 population in Montserrado county, where the capital city is located. Gbarpolu, Bomi, and Grand Cape Mount counties reported no SAO providers; therefore, generalist physicians assume responsibility for provision of all surgical care. SAO providers were consistently available for clinical care in 85%, 77%, and 42% of facilities surveyed, respectively. The national referral hospital had no anesthesiologist despite having 10 surgeons and 5 obstetricians.

## Service Delivery

**Surgical Volume.** Of the 25 facilities that reported recording surgical cases in logbooks, only 15 facilities granted access to their logbooks for this study. Of these, the median annual surgical volume was 626 (IQR, 194–839). The lowest total number of surgical cases performed annually by a single facility was 17, and the highest was 1819. Between 2018 and 2019, a total of 8540 procedures were performed across the 15 hospitals that provided logbook data; this accounts for approximately

**Table 4. Availability of "Highly Recommended"[a] Monitoring Standards and Service Delivery Requirements Reported by 26 Facilities Surveyed in Liberia**

| | Always[b] n (%)[c] | Almost always[b] n (%)[c] | Often[b] n (%)[c] | Sometimes[b] n (%)[c] | Rarely[b] n (%)[c] | Never[b] n (%)[c] |
|---|---|---|---|---|---|---|
| Preoperative (n = 26) | | | | | | |
| Evaluation by anesthetist before surgery | 25 (96) | 1 (4) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Documentation of anesthetic plan | 21 (81) | 5 (19) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Use of WHO Surgical Safety Checklist | 15 (58) | 2 (8) | 5 (19) | 2 (8) | 1 (4) | 1 (4) |
| Intraoperative (n = 26) | | | | | | |
| Anesthesia provider present throughout case | 26 (100) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Continuous pulse oximetry | 22 (85) | 0 (0) | 1 (4) | 1 (4) | 0 (0) | 2 (8) |
| Continuous circulation monitoring[d] | 23 (88) | 1 (4) | 0 (0) | 2 (8) | 0 (0) | 0 (0) |
| Audible monitor signals | 20 (77) | 1 (4) | 0 (0) | 0 (0) | 1 (4) | 4 (15) |
| BP measured every 5 min | 25 (96) | 1 (4) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| $O_2$ supply failure alarm (n = 24)e | 16 (67) | 1 (4) | 1 (4) | 1 (4) | 0 (0) | 5 (21) |
| Postoperative[f] (n = 15) | | | | | | |
| Continuous pulse oximetry | 12 (80) | 1 (7) | 0 (0) | 1 (7) | 1 (7) | 0 (0) |
| Intermittent NIBP monitor | 12 (80) | 1 (7) | 0 (0) | 1 (7) | 1 (7) | 0 (0) |
| Oxygen | 9 (60) | 1 (7) | 0 (0) | 3 (20) | 0 (0) | 2 (13) |
| Suction | 11 (73) | 0 (0) | 0 (0) | 2 (13) | 0 (0) | 2 (13) |
| Self-inflating bag mask | 14 (93) | 0 (0) | 0 (0) | 1 (7) | 0 (0) | 0 (0) |

Abbreviations: BP, blood pressure; HR, heart rate; NIBP, noninvasive blood pressure; PACU, postanesthesia care unit; WFSA, World Federation of Societies of Anaesthesiologists; WHO, World Health Organization.

[a]Highly recommended per WHO-WFSA International Standards for Safe Anesthesia Care.

[b]Always (100% of the time), almost always (76%–99% of the time), often (51%–75% of the time), sometimes (26%–51% of the time), rarely (1%–25% of the time), never (0% of the time).

[c]Percentages have been rounded and may not add up to 100.

[d]Circulation monitoring may include palpation, auscultation, HR display.

[e]Missing survey data.

[f]Only 15 of the 26 facilities surveyed had a PACU.

1,517,102 catchment population, resulting in 563 operations per 100,000 population per year.

**Monitoring Standards.** The facilities included in this survey are considered WHO level 2 and above; however, none adhered to all the WHO-WFSA "Highly Recommended" monitoring standards, as shown in Table 4.[17] Of note, 1 hospital nearly met all the recommendations but lacked carbon dioxide detectors for patients undergoing intubation. Most hospitals reported compliance with preoperative assessment and intraoperative monitoring standards (Table 4). However, nearly half of the hospitals reported inconsistent use of the WHO Surgical Safety Checklist or a local version before surgery (Table 4). Postoperative monitoring practices adhered closely to the WHO-WFSA International standards. Of the 15 facilities with a PACU, 80% had continuous pulse oximetry and noninvasive blood pressure (BP) monitoring available (Table 4). However, less than half (47%) had trained personnel always present in the PACU. Thirty-eight percent of facilities reported having a handover protocol for transfer of care from 1 anesthesia provider to the next.

**Quality Improvement.** Of the facilities that provided an operative logbook for review (n = 15; 58%), 67% tracked intraoperative deaths and 40% tracked 30-day postoperative deaths. Ninety-one percent of the facilities surveyed reported conducting morbidity and mortality review conferences after surgical deaths. However, only 6 of the 26 facilities surveyed reported prospective collection of data on adverse events (such as surgical site infection, stroke, deep vein thrombosis) postoperatively.

## Medication

Availability of "Highly Recommended" medications in the facilities surveyed is shown in Table 5. Three of the facilities surveyed had all the medications in this category. Ketamine, diazepam, bupivacaine, and lidocaine were available in roughly 70% of facilities. Opioids were sparsely available. No facilities had reliable (always available) orally, per os morphine or oxycodone, intravenous (IV)/intramuscular (IM) morphine was always available in only 23% of the facilities, and IV fentanyl in 12%. Resuscitative medications such as epinephrine and atropine were always available in 65% and 73% of facilities, respectively. Muscle relaxants and inhaled anesthetics are considered "Recommended" by WHO-WFSA standards (Supplemental Digital Content, Table 2, http://links.lww.com/AA/D410). Where inhaled anesthetics were used, isoflurane was the most common (available in 46% of facilities), followed by halothane in 24% of facilities. None of the facilities used ether or nitrous oxide (Supplemental Digital Content, Table 2, http://links.lww.com/AA/D410).

## Equipment

Availability of equipment in facilities surveyed is shown in Table 6. Monitors including blood pressure devices and pulse oximeters were always available

**Table 5. Availability of "Highly Recommended"[a] Medications Reported by 26 Facilities Surveyed in Liberia**

| | Always[b] n (%)[c] | Almost always[b] n (%)[c] | Often[b] n (%)[c] | Sometimes[b] n (%)[c] | Rarely[b] n (%)[c] | Never[b] n (%)[c] |
|---|---|---|---|---|---|---|
| Intraoperative medications | | | | | | |
| Ketamine | 18 (69) | 5 (19) | 2 (8) | 1 (4) | 0 (0) | 0 (0) |
| Diazepam | 18 (69) | 6 (23) | 1 (4) | 1 (4) | 0 (0) | 0 (0) |
| Midazolam | 2 (8) | 1 (4) | 2 (8) | 2 (8) | 3 (12) | 16 (62) |
| Fentanyl IV | 3 (12) | 0 (0) | 4 (15) | 1 (4) | 4 (15) | 14 (54) |
| Lidocaine 1% or 2% IV/SQ | 18 (69) | 5 (19) | 1 (4) | 1 (4) | 0 (0) | 1 (4) |
| Lidocaine 5% intrathecal | 9 (35) | 2 (8) | 2 (8) | 1 (4) | 2 (8) | 10 (38) |
| Bupivacaine | 19 (73) | 5 (19) | 2 (8) | 0 (0) | 0 (0) | 0 (0) |
| Isotonic crystalloid IV fluid (n = 24) | 18 (75) | 3 (13) | 3 (13) | 0 (0) | 0 (0) | 0 (0) |
| Resuscitative medications | | | | | | |
| Epinephrine | 17 (65) | 5 (19) | 1 (4) | 1 (4) | 1 (4) | 1 (4) |
| Atropine | 19 (73) | 5 (19) | 2 (8) | 0 (0) | 0 (0) | 0 (0) |
| Dextrose | 18 (69) | 3 (12) | 4 (15) | 0 (0) | 0 (0) | 1 (4) |
| Postoperative analgesics | | | | | | |
| Morphine IV/IM | 6 (23) | 3 (12) | 5 (19) | 1 (4) | 1 (4) | 10 (38) |
| Morphine orally, per os | 0 (0) | 1 (4) | 4 (15) | 0 (0) | 3 (12) | 18 (69) |
| Acetaminophen | 15 (58) | 4 (15) | 3 (12) | 0 (0) | 0 (0) | 4 (15) |
| NSAIDS (eg, ibuprofen) | 16 (62) | 3 (12) | 2 (8) | 0 (0) | 2 (8) | 3 (12) |
| Others | | | | | | |
| Magnesium | 15 (58) | 5 (19) | 4 (15) | 0 (0) | 0 (0) | 2 (8) |

Abbreviations: IM, intramuscular; IV, intravenous; NSAIDS, nonsteroidal anti-inflammatory drugs; SQ, subcutaneous; WFSA, World Federation of Societies of Anaesthesiologists; WHO, World Health Organization.

[a]Highly recommended per WHO-WFSA International Standards for Safe Anesthesia Care.

[b]Always (100% of the time), almost always (76%–99% of the time), often (51%–75% of the time), sometimes (26%–51% of the time), rarely (1%–25% of the time), never (0% of the time).

[c]Percentages have been rounded and may not add up to 100.

**Table 6. Availability of "Highly Recommended"[a] Equipment Reported by 26 Facilities Surveyed in Liberia**

| | Always[b] n (%)[c] | Almost always[b] n (%)[c] | Often[b] n (%)[c] | Sometimes[b] n (%)[c] | Rarely[b] n (%)[c] | Never[b] n (%)[c] |
|---|---|---|---|---|---|---|
| Oropharyngeal airwaya (n = 24) | | | | | | |
| Adult size | 21 (88) | 3 (13) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Pediatric size | 19 (79) | 2 (8) | 2 (8) | 0 (0) | 0 (0) | 1 (4) |
| Laryngoscope | | | | | | |
| Adult size | 22 (85) | 1 (4) | 1 (4) | 0 (0) | 0 (0) | 2 (8) |
| Pediatric size | 20 (77) | 2 (8) | 1 (4) | 0 (0) | 0 (0) | 3 (12) |
| Endotracheal tubes[d] (n = 24) | | | | | | |
| Adult size | 19 (79) | 2 (8). | 0 (0) | 0 (0) | 2 (8) | 1 (4) |
| Pediatric size | 16 (67) | 3 (13) | 1 (4) | 0 (0) | 2 (8) | 2 (8) |
| Intubation aids | | | | | | |
| Magill forceps[d] (n = 24) | 19 (79) | 0 (0) | 2 (8) | 0 (0) | 0 (0) | 3 (13) |
| Bougie | 20 (77) | 0 (0) | 1 (4) | 1 (4) | 0 (0) | 4 (15) |
| Suction pump | 23 (88) | 1 (4) | 2 (8) | 0 (0) | 0 (0) | 0 (0) |
| Suction catheter | 20 (77) | 3 (12) | 3 (12) | 0 (0) | 0 (0) | 0 (0) |
| Self-inflating bag | | | | | | |
| Adult size | 24 (92) | 1 (4) | 0 (0) | 1 (4) | 0 (0) | 0 (0) |
| Pediatric size | 24 (92) | 1 (4) | 1 (4) | 0 (0) | 0 (0) | 0 (0) |
| Miscellaneous[d] (n = 24) | | | | | | |
| IV cannulas (18–24 gauge) | 17 (71) | 6 (25) | 0 (0) | 0 (0) | 1 (4) | 0 (0) |
| Syringes | 17 (71) | 6 (25) | 1 (4) | 0 (0) | 0 (0) | 0 (0) |
| Spinal needles (22, 25 gauge) | 18 (75) | 3 (13) | 1 (4) | 2 (8) | 0 (0) | 0 (0) |
| Sterile gloves | 18 (75) | 5 (21) | 0 (0) | 0 (0) | 1 (4) | 0 (0) |
| Defibrillator | 4 (17) | 2 (8) | 0 (0) | 0 (0) | 2 (8) | 16 (67) |
| Stethoscope (n = 26) | 25 (96) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 1 (4) |
| Pulse oximeter (n = 26) | 23 (88) | 1 (4) | 0 (0) | 1 (4) | 0 (0) | 1 (4) |
| Automatic NIBP monitor | 19 (79) | 2 (8) | 0 (0) | 1 (4) | 0 (0) | 2 (8) |
| Manual NIBP cuff | 18 (75) | 2 (8) | 2 (8) | 0 (0) | 0 (0) | 2 (8) |
| Facemasks | 20 (83) | 2 (8) | 0 (0) | 0 (0) | 0 (0) | 2 (8) |

Abbreviations: IV, intravenous; NIBP, noninvasive blood pressure; WFSA, World Federation of Societies of Anaesthesiologists; WHO, World Health Organization.

[a]Highly recommended per WFSA-WHO International Standards for Safe Anesthesia Care.

[b]Always (100% of the time), almost always (76%–99% of the time), often (51%–75% of the time), sometimes (26%–51% of the time), rarely (1%–25% of the time), never (0% of the time).

[c]Percentages have been rounded and may not add up to 100.

[d]Missing data.

in the ORs in about 75% of facilities. Three facilities reported always having access to manual or electric suction pumps, yet only "almost always" having access to suction catheters. Airway devices for adults and pediatric patients in the ORs were always available in roughly 75% of facilities. Endotracheal tubes for pediatric patients (sizes 3.0–5.0) were always available in 67% of facilities, and available >50% of the time in 20 of 26 hospitals surveyed (83%). Disposable airway equipment was used, then cleaned, and always reused in 42% of facilities and almost always in 21% of facilities. Only 4 hospitals had defibrillators and about half of the hospitals never had electrocardiogram monitors or electrodes. While not currently considered "Highly Recommended" by the WHO-WFSA standards due to unavailability of appropriately robust and suitably priced devices,[17] it is noteworthy that only 2 facilities had continuous waveform capnography readily available. (Supplemental Digital Content, Table 3, http://links.lww.com/AA/D410).

## DISCUSSION

This study describes the current anesthesia capacity in Liberia post-Ebola, as the country devises its NSOAP. Based on this study's findings, none of the facilities surveyed meet the minimum expected WHO-WFSA standards for safe practice of anesthesia. More broadly, the Liberian health system does not meet LCoGS targets for workforce, surgical volume, and POMR tracking. Several critical gaps were identified: The OR density is less than 1/100,000 population in Liberia with roughly 563 operations per 100,000 population per year. The SAO provider density is grossly inadequate with an extremely low number of anesthesiologists relative to surgeons and obstetricians. A significant portion of hospitals remain without reliable oxygen, running water, and electricity. Nonetheless, most hospitals surveyed report adequate preoperative assessment and intraoperative/postoperative monitoring practices.

### Infrastructure

Reliable oxygen, running water, and electricity have been emphasized as minimum standards for hospitals providing surgical and anesthesia care.[17] We found that many hospitals in Liberia do not meet this standard. However, 58% of hospitals in this study had reliable access to running water, which is an improvement from <20% reported by Sherman et al[14] in 2011 and Knowlton et al[15] in 2013. The infrastructure barriers found in this study are otherwise in line with findings from studies of other sub-Saharan African countries in 2010 and 2012, where the percentage of hospitals without dependable running water and electricity ranged from 50% to 78%.[25,26] The lack of reliable public infrastructure in LMICs hinders the provision of adequate surgical and anesthesia care.[27] In Liberia, for instance, where concentrators and cylinders serve as the main source of oxygen in hospitals, unreliable power supply and poor roads are often barriers to oxygen availability.[28] Given the interdependent nature of public goods, investment in infrastructure for safe surgery and anesthesia would have benefits that extend beyond the health system.

The number of functioning ORs in our assessment is estimated to be 0.95/100,000 population, a notable increase from the 0.6/100,000 population reported in the 2011 assessment.[15] This is similar to previous studies reporting an average of 1 functioning OR per 100,000 population in West Africa and far below the rate of >14 functioning ORs per 100,000 population reported in high-income areas.[29] Of the 57 ORs present in hospitals included in this study, only 44 were considered functioning. Lack of necessary staff and equipment for provision of surgery may lead to nonuse of ORs.[30] To meet the international benchmark of 2 operating theaters per 100,000 population,[31] barriers that hinder use of already existing operating theaters in Liberia should be addressed. Similarly, we identified a low proportion of PACU and ICU capacity. There is a paucity of data on critical care and postanesthesia care services in sub-Saharan Africa and its impact on perioperative mortality. However, a study from Rwanda found that 49% of postoperative deaths occurred in the PACU and 24% in the ICU, highlighting the importance of physical infrastructure and space in ensuring adequate perioperative care.[32]

### Workforce

The WFSA recommends a goal of at least 5 specialist physician anesthesia providers (PAP) per 100,000 population.[33] Even with nonphysician anesthesia providers (NPAP) included, the anesthesia workforce density in Liberia is less than 5 per 100,000 population. The 2017 WFSA global anesthesia workforce survey found that 34 of the 37 African countries surveyed still reported an anesthesia provider density of <5 per 100,000 population with NPAPs included.[33] This critical shortage of anesthesia providers is significant as it leads to low surgical volumes, as well as poor surgical outcomes in LMICs.[7,9] These issues are likely pronounced in rural areas, given the maldistribution of anesthesia providers seen in this study.

On a broader scale, the figures are also dismal for the entire specialist surgical workforce. The estimated SAO density of 1.25 per 100,000 population for Liberia is significantly lower than the LCoGS recommendation of 20 per 100,000 population by 2030.[1] Furthermore, there is an alarming discrepancy between the number of surgeons and obstetricians/gynecologists and that of anesthesiologists. With only 1 anesthesiologist in Liberia, there is a significant lack of anesthesia expertise. Even the National Referral Hospital, where one would expect the most complex

cases to be done does not have an anesthesiologist. This has grave consequences for POMR, surgical outcomes, and future work expansion. Nonetheless, the SAO density in Liberia has improved, relative to the 2015 WHO Surgical Workforce Database, where it was reported to be 0.7 per 100,000 population for Liberia.[34] In 2013, the Liberian College of Physicians and Surgeons (LCPS) was established by the government to provide graduate medical training in core specialties.[35] To date, it has graduated 18 obstetrics/gynecology and 16 general surgery providers likely contributing to the increase in SAO density seen in this study. If Liberia wishes to provide graduate medical training in anesthesiology which will be important for improved patient safety and better surgical outcomes, it is vital that fully trained specialist anesthesiologists be recruited to lead the process and to provide the necessary expertise to achieve these goals.

Additionally, the LCoGS SAO definition does not take generalist physicians who provide surgical care into account, as is the case in the 3 counties in this study with no SAO providers. Training and capacity development efforts focused on this population that assumes responsibility for a significant amount of the surgical care are necessary.

### Service Delivery

Based on estimates from the facilities that provided logbook access, the annual surgical volume in Liberia was roughly 563 cases per 100,000 population. This is insufficient and far below the recommended LCoGS target of 5000 cases per 100,000 population.[1] Nonetheless, it is higher than the 330 cases per 100,000 population reported by Knowlton et al[15] in 2011. In terms of quality, only 40% of facilities that provided logbook access were tracking POMR. Liberia likely falls below the threshold annual surgical volume; however, only 58% of the facilities surveyed provided access to their surgical logbooks. There is currently a national MOH mandate for hospitals to report obstetrics case metrics and outcomes in Liberia; this could potentially be expanded to include surgery and anesthesia outcomes to ensure better tracking.

### Equipment

Standards for intraoperative monitoring were met by most of the facilities surveyed. For instance, pulse oximetry was reported to be always available in 85% of hospitals, compared to 64% in 2011.[15] This is noteworthy when compared to results of a 2010 global survey that estimated that in low-income countries (LICs), 23.6% of ORs in urban regions, and 66.5% in rural regions did not have reliable pulse oximetry.[29] The increased availability of pulse oximetry is due to a number of factors. The organization Lifebox has distributed over 25,000 pulse oximeters to LICs including Liberia, since 2012.[36,37] Beyond donations, global pulse oximetry initiatives have emphasized development of affordable, context-specific devices.[37]

### Limitations

This study has limitations. First, we obtained survey responses from structured interviews with key personnel, as opposed to anonymous questionnaires. As a result, responses were dependent on memory of the interviewees and may be affected by responder bias, with interviewees feeling pressured to paint a bleaker or better picture than the reality. To mitigate this bias, we verified survey responses with another member of staff and conducted site visits where possible to review equipment. Second, some sites are missing survey data, often due to the respondent being unsure about an answer and on 1 occasion to a respondent leaving the interview to attend to an emergency and being unable to reschedule. Third, we collected information on operative volume and perioperative mortality retrospectively, and thus results are limited by the accuracy and completeness of logbook data. Hospital policies also restricted access to logbooks in some facilities. Finally, an extensive comparison of the data from this study to prior capacity assessments of Liberia could not be done, as previous studies reported data as proportions rather than individual hospital-level data.

## CONCLUSIONS

Improving surgical and anesthesia capacity in Liberia, post-Ebola, is quite complex. Some of the current deficiencies may be attributable to the disruption caused by the Ebola epidemic of 2014–2016 which claimed over 11,000 lives.[38] The loss of health workers, service disruptions, and increased mistrust of the health system led to decreased utilization of health services including surgery.[39] However, the global response included over US $459 million in aid for Ebola relief in West Africa, some of which was directed toward health system development.[40] Given the critical shortages highlighted in this study, it is worth reflecting on how this massive infusion of Ebola relief funds has translated to progress toward attainment of a resilient health system in Liberia. This study reveals major deficiencies in anesthesia and surgical capacity that would require increased resource allocation and prioritization by the Liberian government to be adequately addressed. All our data and key recommendations will be shared with the MOH for consideration in development of the NSOAP.

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