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Anesthesia Practice and Perioperative Outcomes at Two Tertiary Care Hospitals in Freetown, Sierra Leone

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BACKGROUND: Anesthesia in West Africa is associated with high mortality rates. Critical shortages of adequately trained personnel, unreliable electrical supply, and lack of basic monitoring equipment are a few of the unique challenges to surgical care in this region. This study aims to describe the anesthesia practice at 2 tertiary care hospitals in Sierra Leone.

METHODS: We conducted an observational study of anesthesia care at Connaught Hospital and Princess Christian Maternity Hospital in Freetown, Sierra Leone. Twenty-five percent of the anesthesia workforce in Sierra Leone, resident at both hospitals, was observed from June 2012 to February 2013. Perioperative assessments, anesthetic techniques, and intraoperative clinical and environmental irregularities were noted and analyzed. The postoperative status of observed cases was ascertained for morbidity and mortality.

RESULTS: Between the 2 hospitals, 754 anesthesia cases and 373 general anesthetics were observed. Ketamine was the predominant IV anesthetic used. Both hospitals experienced infrastructural and environmental constraints to the delivery of anesthesia care during the observation period. Vital sign monitoring was irregular and dependent on age and availability of monitors. Perioperative mortality during the course of the study was 11.9 deaths/1000 anesthetics.

CONCLUSIONS: We identified gaps in the application of internationally recommended anesthesia practices at both hospitals, likely caused by lack of available resources. Mortality rates were similar to those in other resource-limited countries. (Anesth Analg 2016;123:213–27)

In 2008, the global volume of surgery was estimated to be 234 million major operations per year, or roughly 1 operation for every 25 persons.[1] Only 8.1 million, or 3.5% of these procedures, occur in the poorest third of the world's population—in countries with an annual per-head expenditure on health ≤$100. Perioperative mortality is estimated to be 5% to 10% in these regions.[1] More recently, research has focused on the role of operative personnel, infrastructure, and training in tackling the global surgical disease burden. However, current studies on perioperative outcomes in resource-constrained countries are often retrospective reviews of operating room (OR) log books and records that likely do not capture the details of anesthesia care practice and intraoperative events. In this study, we examined anesthesia practice in Sierra Leone through direct observation of perioperative tasks, events, and outcomes.

The Republic of Sierra Leone is a country of 5.7 million people located on the West African coast.[2] An 11-year-long civil war (1991–2002) resulted in the death of an estimated 70,000 people, the displacement of one-third of the country's population, and the destruction of infrastructure, including hospitals and the health workforce.[3,4] Unfortunately, although recovery of the country's health system has been steady, it has been inhibited by a paucity of resources, a high poverty index, and the overwhelming magnitude of the human and infrastructure loss recently compounded by an ongoing Ebola hemorrhagic fever outbreak. In 2010, the life expectancy at birth was 57.4 years (rated 201/223 countries worldwide), the maternal mortality rate was 890 per 100,000 births (fifth highest in the world), and the under-5 (U5) mortality rate was 276 deaths per 1000 (highest in the world). In developing countries, many causes of maternal and childhood morbidity and mortality are surgical. In a 2012 survey of the prevalence of surgical conditions and surgically treatable deaths in Sierra Leone, 25% of conditions that respondents reported as needing surgical attention, and 25% of deaths in household members might have been averted by timely surgical care.[3]

In addition to having a very low physician density (0.2/1000—ranked 190/192 in 2008),[2] the government hospitals in Sierra Leone, which provide most of the surgical care for the country's population, have severe shortages in infrastructure and supplies.[4,5] Sierra Leone has 3 government-run tertiary hospitals that also serve as teaching hospitals: Connaught Hospital, Princess Christian Maternity Hospital (PCMH), and Ola During Children's Hospital, all located in Freetown. Surgical and anesthesia care is delivered in the former 2 hospitals.

The goal of this study was to comprehensively examine anesthesia practice in a resource-constrained setting to identify threats and hazards in care that might be addressed with contextually appropriate interventions. The anesthesia

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providers in Connaught Hospital and PCMH represent roughly 25% of Sierra Leone's public anesthesia workforce. Therefore, an examination of practice in these institutions will likely reflect the surgical and anesthesia care accessible to most of the country's population.

METHODS

Study Design

After receiving approval from the Sierra Leone Scientific Review and Ethics Committee and the Johns Hopkins institutional review board, we conducted a prospective observational study of anesthesia practice at 2 study sites. Anesthesia data records were designed and piloted by anesthesia providers at the Johns Hopkins Hospital and modified through a piloting process in Sierra Leone to ensure contextually appropriate data variables and minimize ambiguity in the data collection processes. Data collectors underwent 6 weeks of supervised training in the OR, where they observed and documented anesthesia tasks and operating conditions that could influence a change in anesthetic delivery. They were supervised during the process until a minimum kappa statistic of 0.7 was attained.

Study Setting

This study took place at PCMH and Connaught Hospital, 2 tertiary, government-supported hospitals in Freetown, Sierra Leone. PCMH is the national maternal referral hospital, providing only obstetric and gynecologic services. Connaught Hospital is the national referral hospital for all health services except maternal and nonsurgical pediatric health care. We collected data at both hospitals over a period of 8 months, from June 2012 to February 2013.

Participants

All anesthesia providers at both hospitals were eligible for this study. Participants volunteered, and informed consent was obtained.

Variables and Data Measurement

General information on the hospitals and their infrastructure was collected using the World Health Organization Global Initiative for Emergency and Essential Surgical Care assessment toolkit and a modified version of a hospital questionnaire developed by Jochberger et al.[6] These tools were administered to hospital matrons, statisticians, and hospital management officials.

In addition, anesthesia-related tasks were documented from the time of patient contact in the preoperative area to postoperative handoff. We collected information regarding patient age, gender, and pre-existing conditions to contextualize intraoperative vital signs. Other information was obtained from the anesthetic records and operating list or by verbal confirmation from the anesthesia provider.

During the procedure, we documented anesthesia-related tasks such as medications administered and vital signs monitored or recorded by the anesthetists in the OR. We also noted performance time of events such as anesthesia start and stop times as well as electrical and mechanical disturbances during the operation (Appendix 1). After surgery, we made inquiries about the status of admitted patients daily for up to 30 days to determine discharge date, returns to the OR, or patient death.

Statistical Methods

Anesthesia records and follow-up data were scanned, and abstracted data were entered into a File MakerPro 12 database (FileMaker, Inc., Santa Clara, CA). STATA 11 software (StataCorp LP, College Station, TX) and Microsoft Excel (Microsoft Corp., Redmond, WA) were used to analyze the data. Perioperative details regarding observed cases were reported as frequency distributions.

Role of the Funding Source

The study sponsor, Gradian Health Systems LLC, played no role in the study design, data collection, analysis or interpretation, writing of the manuscript, or decision to submit this report.

RESULTS

Hospital Resources and Infrastructure

Hospital infrastructure and resources are outlined in Table 1. We observed that both hospitals suffered from electrical supply interruptions, and only Connaught Hospital had a consistent water supply. Neither hospital had wall oxygen. Anesthesia medications were obtained through the medical stores of the Ministry of Health and Sanitation, donations from medical missions, and (at Connaught Hospital) a revolving drug fund managed by the hospital anesthesia team. PCMH had no functioning anesthesia machine at the time of this study. Neither hospital had a system for scavenging waste anesthetic gases, and each hospital had 1 physician anesthetist in attendance.

Participants

All 25 nurse anesthetists and 2 physician anesthesiologists volunteered for this study. Data collectors observed 754 anesthetics: 504 at Connaught Hospital and 250 at PCMH. The observed cases represent approximately 59% of all cases performed at Connaught and 29% of cases performed at PCMH within the 8-month study period.

Preoperative Assessment

Observed preoperative tasks such as obtaining consent and medical histories are listed in Table 2. Medical history was documented on patient charts approximately half the time, and the most commonly documented diseases were hypertension (6.8%), diabetes mellitus (3.2%), and asthma (1.2%).

Intraoperative Findings

Tables 3 and 4 list the 10 most common operative procedures observed at each facility. Anesthetic technique varied even with the same operative procedure. Only 4 anesthetic techniques were observed: general anesthesia, regional anesthesia (spinal only), monitored anesthesia care, and local medication given by the surgeon (Table 5). The number of general anesthetics performed includes the unplanned conversions to general anesthesia from regional anesthesia when injection into the subarachnoid space was unsuccessful or analgesic effects terminated before the conclusion of surgery (25 cases at Connaught and 37 cases at PCMH).

Table 1. World Federation of Societies of Anesthesiologists International Standards Assessment at the 2 Study Sites

	General	Connaught	PCMH
Level 1[a]	Provides emergency measures in the treatment of 90%–95% of trauma and obstetrics cases (excluding cesarean delivery)	Available	Available
Level 2[a]	District or provincial hospital (e.g., with100–300 beds) and adequately equipped major and minor operating rooms	Available (275 beds)	Available (145 beds)
	Short-term treatment of 95%–99% of the major life-threatening conditions	Available	Available
Level 3[a]	A referral hospital of 300–1000 or more beds with basic intensive care facilities; treatment aims are the same as for level 2 with the addition of ventilation in OR and ICU	Does not meet criteria	Does not meet criteria
	Prolonged endotracheal intubation	Not available	Not available
	Thoracic trauma care	Available	Not applicable
	Hemodynamic and inotropic treatment	Available	Available
	Complex neurological and cardiac surgery	Not available	Not applicable
	Basic ICU patient management and monitoring for up to 1 wk: all types of cases, but possibly with limited provision for multiorgan system failure	Not available	Not available
	Hemodialysis	Not available	Not available
	Prolonged respiratory failure	Not available	Not available
	Metabolic care or monitoring	Not available	Not available
	Essential procedures	**Connaught**	**PCMH**
Level 1	Normal delivery	Not applicable	Available
	Uterine evacuation	Not applicable	Available
	Circumcision	Available	Not applicable
	Hydrocele reduction, incision, and drainage	Available	Not applicable
	Wound suturing	Available	Available
	Control of hemorrhage with pressure dressings	Available	Available
	Débridement and dressing of wounds	Available	Available
	Temporary reduction of fractures	Available	Not applicable
	Cleaning or stabilization of open and closed fractures	Available	Not applicable
	Chest drainage (possibly) abscess drainage	Available	Available
Level 2	Cesarean delivery	Not applicable	Available
	Laparotomy (usually not for bowel obstruction)	Available	Available
	Amputation	Available	Not applicable
	Hernia repair	Available	Not applicable
	Tubal ligation	Not applicable	Available
	Closed fracture treatment and application of plaster of Paris	Available	Not applicable
	Acute open orthopedic surgery: e.g., internal fixation of fractures	Available	Not applicable
	Eye operations, including cataract extraction	Available	Not applicable
	Removal of foreign bodies (e.g., in the airway)	Available	Not applicable
	Emergency ventilation and airway management for referred patients such as those with chest and head injuries	Available	Not applicable
Level 3	Facial and intracranial surgery	Otolaryngology only	Not applicable
	Bowel surgery	Available	Not applicable
	Pediatric and neonatal surgery	Available	Not applicable
	Thoracic surgery	Available	Not applicable
	Major eye surgery	Available	Not applicable
	Major gynecological surgery (e.g., vesicovaginal repair)	Not applicable	Available
	Personnel	Connaught	PCMH
Level 1	Paramedical staff/anesthetic officer (including on-the-job training) who may have other duties as well	Available	Not available
	Nurse-midwife	Available	Available
Level 2	District medical officers, senior clinical officers, nurses, and midwives	Available	Available
	Visiting specialists or resident surgeon and/or obstetrician–gynecologist	Available	Available
	Nurse anesthetists	Available (10)	Available (13)
Level 3	Clinical officers and specialists in anesthesia and surgery	Available	Available
	Drugs	**Connaught**	**PCMH**
Level 1	Ketamine 50 mg/mL injection	Available	Available
	Lidocaine 1% or 2%	Available	Available
	Diazepam or midazolam injection	Available	Available
	Pethidine injection	Not available	Not available
	Morphine	Available	Available
	Epinephrine (adrenaline)	Available	Available
	Atropine	Available	Available
	Appropriate inhalational anesthetic if vaporizer available	Available	Not available (no vaporizer)

(*Continued*)

Table 1. Continued

Level 2	Thiopental powder or propofol	Available	Available
	Suxamethonium bromide powder	Available	Available
	Pancuronium	Not available	Not available
	Neostigmine injection	Available	Available
	Ether, halothane, or other inhalational anesthetics	Available (halothane)	Available (no vaporizer)
	Lidocaine 5% heavy spinal solution	Not available	Not available
	Bupivacaine 0.5% heavy or plain	Available	Available
	Hydralazine injection	Available	Available
	Furosemide injection	Available	Available
	Dextrose 50% injection	Available	Available
	Aminophylline injection	Available	Not available
	Ephedrine ampules	Available	Available
	Hydrocortisone	Available	Available
	Nitrous oxide	Not available	Not available
Level 3	Propofol	Available	Available
	Nitrous oxide	Not available	Not available
	Various modern neuromuscular-blocking agents	Available	Available
	Various modern inhalational anesthetics	Not available	Not available
	Various inotropic agents	Available	Available
	Various IV antiarrhythmic agents	Not available	Not available
	Nitroglycerine for infusion	Not available	Not available
	Calcium chloride 10% IM injection	Available	Calcium gluconate available
	Potassium chloride 20% injection for infusion	Not available	Available
	Equipment: capital outlay	**Connaught**	**PCMH**
Level 1	Adult and pediatric self-inflating breathing bags with masks	Available	Available
	Foot-powered suction	Available	Available
	Stethoscope, sphygmomanometer, and thermometer	Available	Available
	Pulse oximeter	Intermittently available	Intermittently available
	Oxygen concentrator or tank oxygen and a draw-over vaporizer with hoses	Available	Available
	Laryngoscopes and bougies	Available	Available
Level 2	Complete anesthesia, resuscitation, and airway management systems including reliable oxygen sources	Intermittently available	Intermittently available
	Vaporizer(s)	Available	Not available
	Hoses and valves	Available	Not available
	Bellows or bag to inflate lungs	Available	Available
	Facemasks (sizes 00–5)	Available	Available
	Work surface and storage	Available	Available
	Pediatric anesthesia system	Available	Not available
	Oxygen supply failure alarm; oxygen analyzer	Not available	Not available
	Adult and pediatric resuscitator sets	Available	Not available
	Pulse oximeter, spare probes, adult, and pediatric[b]	Intermittently available	Intermittently available
	Capnograph[b]	Not available	Not available
	Defibrillator (1 per OR suite/ICU)[b]	Not available	Not available
	ECG monitor[b]	Not available	Not available
	Laryngoscope, Macintosh blades 1–3 (4)	Available	Available
	Oxygen concentrator(s)/cylinder	Available	Available
	Foot or electric suction	Available	Available
	IV pressure infusor bag	Not available	Not available
	Adult and pediatric resuscitator sets	Ambubag available	Ambubag available
	Magill forceps (adult and child), intubation stylet, and/or bougie	Not available	Intermittently available
	Spinal needles 25 G	Available	Available
	Nerve stimulator	Not available	Not available
	Automatic noninvasive blood pressure monitor	Not available	Available
Level 3	ECG monitor[b]	Not available	Not available
	Anesthesia ventilator, reliable electric power source with manual override	Not available	Not available
	Infusion pumps (2 per bed)	Not available	Not available
	Pressure bag for IV infusion	Not available	Not available
	Electric or pneumatic suction	Available	Available
	Oxygen analyzer[b]	Not available	Not available
	Thermometer (temperature probe[b])	Available	Available
	Electric warming blanket	Not available	Not available
	Electric overhead heater	Not available	Available
	Infant incubator	Not available	Not available
	Laryngeal mask airways sizes 2, 3, 4 (3 sets per OR)	Intermittently available	Intermittently available
	Intubating bougies, adult, and child (1 set per OR)	Intermittently available	Intermittently available

(*Continued*)

Table 1. Continued			
	Anesthetic agent (gas and vapor) analyzer	Not available	Not available
	Depth of anesthesia monitors are being increasingly recommended for cases at high risk of awareness but are not standard monitoring in many countries	Not available	Not available
	Equipment: disposable	**Connaught**	**PCMH**
Level 1	Examination gloves	Available	Available
	IV infusion/drug injection equipment	Intermittently available	Intermittently available
	Suction catheters size 16 FG	Available	Available
	Airway support equipment, including airways and tracheal tubes	Available	Available
	Oral and nasal airways	Available	Available
Level 2	ECG electrodes	Not available	Not available
	IV equipment (minimal fluids: normal saline, lactated Ringer's solution, and dextrose 5%)	Available	Available
	Pediatric giving sets	Available	Not applicable
	Suction catheters, size 16 FG	Available	Not available
	Sterile gloves, sizes 6–8	Available	Available
	Nasogastric tubes, sizes 10–16 FG	Available	Intermittently available
	Oral airways, sizes 000–4	Intermittently available	Intermittently available
	Tracheal tubes, sizes 3–8.5 mm	Available	Intermittently available
	Spinal needles, sizes 22 G and 25 G	Available	Available
	Batteries, size C	Available	Available
Level 3	Ventilator circuits	Available	Not available
	Yankauer suckers	Available	Available
	Giving sets for IV infusion pumps	Not available	Not available
	Disposables for suction machines	Intermittently available, recycled	Intermittently available, recycled
	Disposables for capnography, oxygen analyzer, in accordance with manufacturers' specifications: sampling lines, water traps, connectors, and filters-fuel cells	Not available	Not available

ECG = electrocardiography; ICU = intensive care unit; OR = operating room; PCMH = Princess Christian Maternity Hospital.

[a]Level 1: Highly recommended; level 2: recommended; level 3: suggested.

[b]According to the World Federation of Societies of Anesthesiologists, it is preferable to combine these modalities all in 1 unit.

At Connaught Hospital, 25 of 163 (15.3%) attempted spinal anesthetics were converted to general anesthetic; the incidence of similar conversions at PCMH was 37 of 200 (18.5%). However, at Connaught, when spinal anesthesia failed, only 12% were converted to general anesthesia with an endotracheal tube compared with 2.7% (1 of 37) at PCMH, where all patients then received total IV anesthetic and required manual bag-valve-mask ventilation.

Halothane was the only inhalational anesthetic available, bupivacaine the sole spinal anesthetic, and lignocaine the sole local anesthetic available. PCMH was unable to deliver inhalational anesthesia; therefore, all general anesthetics were performed using IV ketamine (doses ranged from 50 to 900 mg), thiopentone, or propofol (Table 5).

Intraoperative vital sign monitoring depended on the patient's age and the availability of functional monitors and power supply. Power outage occurred during 7.8% of observed cases (Table 6). Both hospitals were limited in the number of intraoperative monitors available, and their utility varied among patient types. At Connaught Hospital, blood pressure was measured in 35.9% (52/145) of pediatric cases but in 90.5% (325/359) of adult cases. In contrast, pulse oximetry was monitored in 95.2% of children and 86.1% of adults. At PCMH, blood pressure and pulse oximetry were monitored in 98% and 88.8% of cases, respectively, but did not seem to relate to age group. Both hospitals reported having a recovery room, although no support staff was available for patient care in these areas. Clinical intraoperative events such as hypotension were noted with frequencies as described in Table 6. There were 37 cases in which significant hypotension was observed, and in these cases, 100% were treated with intravascular fluids, 45.9% with autologous blood transfusions, and 81.1% received vasoactive agents, which included epinephrine, ephedrine, and atropine.

Postoperative Care and Outcomes

The postoperative care period was defined as the time from OR departure to discharge, death, or 30 days, whichever came first. In the immediate postoperative period, 22.7% (171/754) of observed patients were placed in a designated recovery room or area; 52% (90/171) of these cases were pediatric patients with age <18 years and received intermittent clinical assessment by anesthesia providers; 65.1% (491/754) of patients were placed in a hallway outside the OR until a nursing team member was available to transfer the patient to the ward; 0.4% (3/754) had immediate ward transfers; 0.4% (3/754) were transferred directly to the high-dependency unit; and 11.4% (86/754) were either discharged home immediately or could not be traced in the immediate postoperative period.

At Connaught Hospital, the 30-day in-hospital mortality rate was 1.4% (7/504) among observed cases and the 30-day in-hospital mortality rate at PCMH was 0.8% (2/250) with mortality in pregnancy-related conditions occurring in 0.5% (1/210). Thirty cesarean deliveries resulted in stillbirth deliveries, 6.7% (2/30) of which were documented preoperatively.

Postoperative vital sign monitoring was performed in 17.1% (129/754) of all cases; 96.9% (125/129) of which were

Table 2. Description of Patient Demographics and Observed Preoperative Assessments

Characteristic	Total observed cases, *n* (%)	Connaught, *n* (%)	PCMH, *n* (%)
Total	754	504	250
Age (y)			
<1	23 (3.05)	23 (4.6)	0 (0)
1–17	135 (17.9)	121 (24.2)	14 (5.6)
18–50	466 (61.8)	236 (46.8)	230 (92)
>50	122 (15.9)	120 (23.8)	2 (0.8)
Age unknown	8 (1.1)	4 (0.8)	4 (1.6)
Female	427 (56.6)	177 (35)	250 (100)
Emergent	74 (9.8)	8 (1.6)	66 (26.4)
ASA classification			
ASA I	408 (54.1)	340 (67.5)	68 (27.2)
ASA II	284 (37.7)	131 (26)	153 (61.2)
ASA III	34 (4.5)	10 (1.98)	24 (9.6)
ASA IV	4 (0.5)	2 (0.4)	2 (0.8)
ASA unknown	24 (3.2)	21 (4.2)	3 (1.2)
"Nil per os" observed in elective cases (Connaught: *n* = 492) (PCMH: *n* = 183)	675 (99.9)	492 (100)	182 (99.5)
Preoperative interview observed or documented	33 (4.4)	6 (1.2)	27 (10.8)
Anesthesia consent found on file	749 (99.3)	500 (99.2)	249 (99.6)
Allergies documented	211 (28)	177 (35.1)	34 (13.6)
Medication history documented	207 (27.5)	163 (32.3)	44 (17.6)
Medical history documented	360 (47.8)	284 (56.4)	76 (30.4)
Social history documented	304 (40.3)	251 (49.8)	53 (21.2)
Laboratory results documented on file	367 (48.7)	319 (63.3)	48 (19.2)
Observed identification of patient (verbally or with name tag)	252 (33.4)	155 (30.8)	97 (38.8)
Preoperative ECG done	5 (0.7)	4 (0.8)	1 (0.4)
Preoperative CXR done	4 (0.5)	3 (0.6)	1 (0.4)
WHO preoperative team review of anticipated challenges performed	4 (0.5)	2 (0.4)	2 (0.8)
Preoperative VS done and recorded	399 (52.9)	256 (50.8)	143 (57.2)

ASA = American Society of Anesthesiologists; CXR = chest x-ray; ECG = electrocardiogram; PCMH = Princess Christian Maternity Hospital; VS = vital signs; WHO = World Health Organization.

Table 3. Anesthesia Techniques Performed for 10 Most Common Surgical Operations at Connaught Hospital

Surgical procedures observed	Mean surgery duration in min (SD)	All anesthesia	GA, *n* (%)	SA, *n* (%)	Local, *n* (%)	Monitored anesthesia care, *n* (%)	Spinal or local converted to GA, *n* (%)
All cases observed		504	259	138	55	24	28
Hernia repair	39 (22)	181 (35.9)	78 (30.1)	60 (43.5)	30 (57.7)	0 (0)	13 (44.8)
Appendectomy	38 (18)	52 (9.6)	37 (14.3)	8 (5.8)	0 (0)	0 (0)	7 (24.1)
Endoscopy	9 (9)	32 (4.8)	3 (0.6)	1 (0.7)	1 (1.9)	24 (100)	0 (0)
Prostatectomy	83 (34)	30 (5.6)	1 (0.4)	26 (18.8)	0 (0)	0 (0)	3 (10.3)
Lumpectomy	32 (18)	30 (5.6)	19 (7.3)	0 (0)	10 (19.2)	0 (0)	1 (3.4)
Hydrocelectomy ± hernia repair	31 (16)	23 (4.3)	10 (3.9)	10 (7.3)	1 (1.9)	0 (0)	2 (6.9)
Laparotomy	83 (31)	18 (3.3)	18 (6.9)	0 (0)	0 (0)	0 (0)	0 (0)
Amputation	59 (30)	12 (2.4)	2 (0.8)	10 (7.3)	0 (0)	0 (0)	0 (0)
Thyroidectomy	50 (14)	11 (2)	11 (4.2)	0 (0)	0 (0)	0 (0)	0 (0)
Sequestrectomy	28 (18)	11 (2)	10 (3.9)	0 (0)	0 (0)	0(0)	1 (3.4)

GA = general anesthesia; SA = spinal anesthesia.

pulse oximetry assessments that identified 9 cases of hypoxemia. The postoperative status of 51 cases (6.7%) could not be verified owing to inconclusive ward documentation. The composition of anesthesia technique and case type in these cases did not vary significantly from the remainder of the observed cohort.

DISCUSSION

Our study captured anesthesia delivery practice by 25% of the Sierra Leonean anesthesia workforce stationed in these hospitals, which serve as teaching hospitals for anesthesia trainees and the sole medical school in the country. Nurse anesthetists currently make up approximately 98% of anesthesia providers in the Sierra Leonean public health sector and performed 91% of the cases observed with minimal or no direct physician oversight. Nurse anesthetists in Sierra Leone go through a United Nations Population Fund-sponsored 12-month anesthesia training program with prerequisite training in nursing (3-year program) and midwifery (2.5 years). They also receive annual update courses coordinated by the Sierra Leone Association of Nurse Anesthetists with the support of the United Nations Population Fund and other nongovernmental organizations.

Table 4. Anesthesia Techniques Performed for 10 Most Common Surgical Operations at Princess Christian Maternity Hospital

Surgical procedures observed	Mean surgery duration in min, (SD)	All anesthesia	GA, *n* (%)	SA, *n* (%)	Local, *n* (%)	Monitored anesthesia care, *n* = 0	Spinal or local converted to GA, *n* (%)
All cases observed		250	49	163	1	0 (0)	37
Cesarean delivery	59 (19)	192 (76.8)	25 (51)	138 (84.7)	0 (0)	0 (0)	29 (78.4)
Laparotomy[a]	73 (31)	14 (5.6)	10 (20.4)	3 (1.8)	0 (0)	0 (0)	1 (2.7)
Myomectomy ± cystectomy	90 (30)	13 (5.2)	1 (2)	10 (6.1)	0 (0)	0 (0)	2 (5.4)
Total or subtotal hysterectomy	83 (18)	10 (4)	1 (2)	7 (4.3)	0 (0)	0 (0)	2 (5.4)
Cystectomy	52 (28)	7 (2.8)	1 (2)	3 (1.8)	0 (0)	0 (0)	3 (8.1)
Fallopian/ovarian procedures[a]	63 (9)	6 (2.4)	4 (8.2)	2 (1.2)	0 (0)	0 (0)	0 (0)
Uterine evacuation	18 (10)	4 (1.6)	4 (8.2)	0 (0)	0 (0)	0 (0)	0 (0)
Uterine repair	49 (0)	1 (0.4)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)
Vaginal repair	10 (0)	1 (0.4)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)
Vulva repair	23 (0)	1 (0.4)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)

GA = general anesthesia; SA = spinal anesthesia.
[a]Includes ectopic pregnancy cases.

World Federation of Societies of Anesthesiologists Standards and Procedures Performed

In 2010, the World Federation of Societies of Anesthesiologists (WFSA) published standards intended to improve the safe practice of anesthesia worldwide, even in resource-limited settings.[7] These guidelines outline "suggested," "recommended," and "highly recommended" aspects of hospital infrastructure, supplies, and professional standards and provide a designation of 3 levels of hospital care: small hospital, district/provincial hospital, and referral (tertiary-care) hospital. Each level is expected to exceed the standards outlined for the preceding level. We assessed these essential elements and compared those of the study hospitals with the WFSA standards/guidelines (Table 1). Both hospitals provide some degree of level 3 care, because they are considered tertiary-care, referral hospitals in the governmental hospital system. They also provide many surgical services described for tertiary-level hospitals. However, by the size and resources available, the sites more closely resemble WFSA level 2 facilities.

Available Resources and Perioperative Practice

Anesthesia practice is influenced by available resources, equipment, and comfort of the provider. Thus, standards and protocols will differ between hospitals, even within the same cities. It is not surprising, therefore, that regional anesthesia was preferred at PCMH (65.2%) and general anesthesia was the preferred technique at Connaught Hospital (56.9%; Table 5). Although several anesthesia delivery systems were on-site at both hospitals, none was functional at PCMH. At Connaught Hospital, a Glostavent® (Diamedica Ltd., UK) with a draw-over system, which had a nonfunctional ventilator and oxygen concentrator, was retired in the early stages of the study because of disrepair and a Compact-3 (a type of Boyle machine) that was often in different stages of repair was in intermittent use during the course of the study. Compressed oxygen was unavailable at PCMH for the course of the study, and supplemental oxygen was delivered through an oxygen concentrator. At Connaught Hospital, a concentrator was used in 55.2% (186/337) of all cases that required supplemental oxygen; 95 of such patients were also ventilated with an anesthesia machine. The anesthesia machine, which is designed to be used with an oxygen cylinder or pipeline oxygen, had been adapted for use with a standalone oxygen concentrator although neither the concentrator nor the machine was used with an oxygen analyzer to measure fraction of inspired oxygen. Moreover, because oxygen concentrators require electricity, the frequent power outages observed present a potential hazard to patients who require consistent intraoperative oxygen supplementation.

WFSA-recommended practice on preoperative anesthesia evaluation is a comprehensive assessment and documentation of relevant findings on the patient's status. In this study, we documented preoperative reviews that were recorded on file or witnessed by the data collector. Although previous day clinical review was not routine practice at these hospitals, such interactions, if they occurred, were not captured in this study if undocumented in the patient's chart. Infrequent monitoring in the postoperative period could be partially attributed to the allocation of available monitoring devices to the OR.

Narcotic medications are highly regulated in Sierra Leone, and this likely impacts its clinical use, as seen in this study, in which 3.6% (27/754) of cases were administered any form of narcotic (morphine or tramadol).

Ketamine

When a general anesthetic was used at PCMH, it was always with anesthetic doses of ketamine (86/86 cases), and only 7 patients of this cohort were tracheally intubated. Like in many parts of the developing world, ketamine was the most commonly used IV anesthetic administered during the study period.[8] Ketamine does not depress ventilation, is likely to maintain hemodynamic stability, and has a high margin of safety.[9] It is especially favorable for use by those not trained in anesthesia or when basic monitoring equipment is lacking. In the obstetric patient, it can be particularly useful in cases of obstetric hemorrhage; however, anesthetic doses should be used with caution in patients who do not have a definitive airway and in those with pre-eclampsia or hypertension.

Spinal Converted to General Anesthesia

During conversion of spinal to general anesthesia, providers at PCMH were often hesitant to secure the airway by

Table 5. Intraoperative Anesthesia Procedures and Medications

Procedure	Total (*n* = 754), *n* (%)	Connaught (*n* = 504), *n* (%)	PCMH (*n* = 250), *n* (%)
Airway management[a]			
Endotracheal intubation	119 (15.8)	112 (22.2)	7 (2.8)
Laryngeal mask airway	11 (1.5)	11 (2.2)	0 (0)
Oropharyngeal airway ± facemask	124 (16.4)	117 (23.2)	7 (2.8)
Facemask	445 (59)	212 (42.1)	226 (93.2)
None	169 (22.4)	159 (31.5)	10 (4.0)
Anesthesia techniques			
General anesthesia	373 (49.5)	287 (56.9)	86 (34.4)
GA, inhalational	205 (27.2)	205 (40.7)	0 (0)
GA, total IV anesthesia	168 (22.3)	82 (16.3)	86 (34.4)
GA converted from SA/LA	65 (8.6)	28 (5.6)	37 (14.8)
Spinal anesthesia	301 (39.9)	138 (27.4)	163 (65.2)
Monitored anesthesia care	24 (3.2)	24 (4.8)	0 (0)
Local anesthesia	56 (7.4)	55 (10.9)	1 (0.4)
Anesthetic/adjunct agents utilized			
Halothane	197 (26.1)	197 (39.1)	0 (0)
Ketamine	337 (44.7)	246 (48.8)	91 (36.4)
Thiopentone	11 (1.5)	3 (0.6)	8 (2.4)
Propofol	17 (2.3)	15 (3.0)	2 (0.8)
Succinylcholine	117 (15.5)	106 (21.0)	11 (4.4)
Atracurium	81 (10.7)	78 (15.5)	3 (1.2)
Vecuronium	2 (0.3)	1 (0.2)	1 (0.4)
Neostigmine	43 (5.7)	41 (8.1)	2 (0.8)
Atropine	361 (47.9)	283 (56.2)	78 (31.2)
Epinephrine	1 (0.1)	0 (0)	1 (0.4)
Ephedrine	99 (13.1)	13 (2.6)	86 (34.4)
Preop-/intraoperative antibiotic administered	424 (56.2)	180 (35.7)	244 (97.6)
Opioid/opioid agonist			
Morphine	8 (1.1)	0 (0)	8 (3.2)
Tramadol	19 (2.5)	7 (1.4)	12 (4.8)
No analgesic	727 (96.4)	497 (98.6)	230 (92.0)
Supplemental oxygen source			
Pipeline oxygen	0 (0)	0 (0)	0 (0)
Oxygen cylinder	151 (20)	151 (30.0)	0 (0)
Oxygen concentrator	427 (56.6)	186 (36.9)	241 (96.4)
Room air	207 (27.5)	176 (34.9)	31 (12.4)

GA = general anesthesia; LA = local anesthesia; PCMH = Princess Christian Maternity Hospital; SA = spinal anesthesia.
[a]Used exclusively or in conjunction with other listed airway management devices.

using endotracheal intubation (in patients who are at risk for aspiration pneumonia) for concern of potential airway loss and risks of hypoxia/death. A contributing factor to the frequency of general anesthesia without an endotracheal tube at PCMH may relate to the lack of a functional anesthetic machine there. Although the hospital owned 2 recent-model anesthesia machines, neither was in clinically operational condition because of issues related to lack of compressed gas, absence of carbon dioxide-absorbing granules, and lack of maintenance support.

The providers attributed the failed spinal anesthetics to the following: inability to access the subarachnoid space (in some instances after multiple attempts), experience of the anesthesia provider or the potency of the anesthetic drug, and/or the extended duration (in a few instances) of the surgical cases. A prospective study on failed obstetric spinal anesthesia in Nigeria reported that the technique and level of experience of the anesthesia provider were significantly related to the rate of failure.[10] The significant incidence of failed spinal anesthesia indicates a need for reinforced training on spinal anesthesia procedures and endotracheal anesthesia techniques in the urgent/emergent clinical situation. It is interesting that 53 of 54 (98%) cesarean deliveries performed with the patient under IV general anesthesia were conducted without physical airway protection with a cuffed endotracheal tube. A study on obstetric mortality in Nigeria showed that failed airway management remains a significant contributor to anesthesia-related maternal mortality.[11]

Perioperative Mortality

We estimated that mortality was 8 deaths/1000 anesthetics at PCMH and 13.8 deaths/1000 anesthetics at Connaught Hospital. These rates are comparable with reported mortality rates of countries such as Malawi (10.5 deaths/1000 anesthetics),[12] Zimbabwe (2.9 deaths/1000 anesthetics),[13] and Togo (20.5 deaths/1000 anesthetics).[14] In the United States, anesthesia-related mortality is estimated to be approximately 1.1 death/1,000,000 anesthetics.[15]

The American Society of Anesthesiologists (ASA) physical status classification system is a proven predictor of postoperative outcomes.[16,17] In our study, we observed only 5% of patients who were ASA III to IV compared with 56.5% in the U.S.-based study of outpatient "remote" anesthesia venues.[18] It is possible that patients with significant comorbidities have deterrents to presenting to Sierra Leone referral

Table 6. Intraoperative Events (Clinical and Nonclinical)

Event	Definition	Total (*n* = 754), *n* (%)	Connaught (*n* = 504), *n* (%)	PCMH (*n* = 250), *n* (%)
Clinical				
Systolic hypertension				
Acute moderate	>140 mm Hg for ≥10 min	69 (9.2)	49 (9.7)	20 (8.0)
Acute severe	>180 mm Hg for ≥10 min	11 (1.5)	9 (1.8)	2 (0.8)
Sustained moderate	>140 mm Hg for ≥15 min	132 (17.5)	117 (23.2)	45 (18.0)
Sustained severe	>180 mm Hg for ≥15 min	26 (3.4)	23 (4.6)	3 (1.2)
Not recorded	Not monitored	132 (17.5)	127 (25.2)	5 (2.0)
No systolic hypertension		354 (47.0)	179 (35.5)	175 (70.0)
Systolic hypotension				
Acute moderate	<90 mm Hg for ≥10 min	12 (1.6)	1 (0.2)	11 (4.4)
Acute severe	<80 mm Hg for ≥10 min	4 (0.5)	1 (0.2)	3 (1.2)
Sustained moderate	<90 mm Hg for ≥15 min	10 (1.3)	0 (0.0)	10 (4.0)
Sustained severe	<80 mm Hg for ≥15 min	11 (1.5)	5 (1.0)	6 (2.4)
Not recorded	Not monitored	132 (17.5)	127 (25.2)	5 (2.0)
No systolic hypotension		585 (77.6)	370 (73.4)	215 (86.0)
Diastolic hypertension				
Acute moderate	≥90 mm Hg for ≥10 min	30 (4.1)	26 (5.2)	4 (1.6)
Acute severe	≥110 mm Hg for ≥10 min	7 (8.1)	4 (0.8)	3 (1.2)
Sustained moderate	≥90 mm Hg for ≥15 min	75 (8.5)	54 (10.7)	21 (8.4)
Sustained severe	≥110 mm Hg for ≥15 min	18 (2.4)	15 (3.0)	3 (1.2)
Not recorded	Not monitored	132 (17.5)	127 (25.2)	5 (2.0)
No diastolic hypertension		492 (65.3)	278 (55.2)	214 (85.6)
Tachycardia (*n* = 396)[a]				
Acute moderate	>100 bpm for ≥10 min	31 (4.1)	20 (4.0)	7 (2.8)
Acute severe	>110 bpm for ≥10 min	61 (8.1)	26 (5.2)	17 (6.8)
Sustained moderate	>100 bpm for ≥15 min	64 (8.5)	39 (7.7)	24 (9.6)
Sustained severe	>110 bpm for ≥15 min	317 (42.0)	140 (27.8)	96 (38.4)
Not recorded	Not monitored	60 (8.0)	30 (6.0)	27 (10.8)
No tachycardia		221 (29.3)	142 (28.2)	79 (11.6)
Bradycardia				
Acute moderate	<60 bpm for ≥10 min	11 (1.5)	8 (1.6)	3 (1.2)
Acute severe	<50 bpm for ≥10 min	3 (0.4)	3 (0.6)	0 (0.0)
Sustained moderate	<60 bpm for ≥15 min	11 (1.5)	10 (2.0)	1 (0.4)
Sustained severe	<50 bpm for ≥15 min	4 (0.5)	4 (0.8)	0 (0.0)
Not recorded	Not monitored	64 (8.5)	37 (7.3)	27 (10.8)
No bradycardia		661 (87.7)	442 (87.7)	219 (87.6)
Hypoxia				
Acute moderate	<90% for ≥10 min	4 (0.5)	4 (0.8)	0 (0.0)
Acute severe	<85% for ≥10 min	7 (0.9)	2 (0.4)	5 (2.0)
Sustained moderate	<90% for ≥15 min	5 (0.7)	4 (0.8)	1 (0.4)
Sustained severe	<85% for ≥15 min	8 (1.1)	4 (0.8)	4 (1.6)
Not recorded	Not monitored	84 (11.1)	57 (11.3)	27 (10.8)
No hypoxia		646 (85.7)	433 (85.9)	213 (85.2)
Nonclinical				
Power outage		59 (7.8)	20 (4)	39 (15.6)
Monitoring equipment malfunction/ unavailability		56 (7.4)	36 (7.1)	20 (8)

bpm = beats per minute; PCMH = Princess Christian Maternity Hospital.
[a]Does not include patients <12 y.

hospitals or are not considered candidates for surgical treatment in low-resource environments. Also, the lower average age of the population and lack of primary medical care may result in lower levels of diagnosed chronic disease. The low numbers of ASA III to IV patients could be responsible for the low rates of morbidity and mortality that we observed.

LIMITATIONS

Our assessment of perioperative mortality was limited by our inability to capture cases that presented outside the normal weekday OR schedule hours (8:30 AM to 4:30 PM). Thus, anesthesia procedures performed outside of these hours/days were not observed by the study team and were not included in this analysis. These cases may likely have included emergent cases, which may have been performed under slightly different conditions with potentially different outcomes from the observed cases.

CONCLUSIONS

Understanding the current state of anesthesia care practice is an important step in determining appropriate educational and clinical interventions for building anesthesia capacity in any location. It is especially important in challenging clinical environments such as resource-constrained countries that have inconsistent access to supplies and functional equipment, inadequate

numbers of trained personnel, and limited opportunities for collaboration and expert consultation. In these locations, specialty-trained nurses often provide anesthesia care to a large segment of the population and will likely continue to do so in the absence of a growing physician workforce.

Our observations identified gaps in the application of internationally recommended safe anesthesia practices. These gaps could be related to a lack of available training and resources such as protocols regarding optimal airway management in obstetric anesthesia delivery.

Impediments to safe anesthesia care delivery can be identified by engaging local providers and stakeholders in the examination of their clinical processes using systematic process improvement techniques such as the Failure Modes and Effects Analysis.[19,20] Potential solutions should include designing medical curricula specifically tailored to the needs of the local clinical providers. In addition, in situ, low-cost medical simulation may enhance anesthesia training by targeting performance demonstration and improvement with no risk to patients. Also, anesthesia equipment design and development should consider the characteristics of the environments of end users, the availability of biomedical support, the ease of repair, and the local availability of replacement parts. Anesthesia delivery systems such as the Universal Anaesthesia Machine® (Gradian Health Systems, New York, NY) and the Glostavent® devices, which have draw-over vaporizer systems and inbuilt oxygen concentrators, are specifically designed to overcome some of these issues. Such innovations should be accompanied by local biomedical engineering capacity-building (education, personnel, and infrastructure) to tackle equipment-related issues and improve durability and sustainability.

By thoroughly examining the process of anesthesia delivery in resource-constrained environments, we can better analyze the threats and hazards to care and focus on contextually appropriate interventions to address practice-based systems improvement and relevant curricula for local providers.

This study addresses this need by documenting anesthesia care practice in 2 tertiary hospitals in Freetown, Sierra Leone.

APPENDIX 1

OBSERVATIONAL PHASE

PRE- OP ANESTHESIA EVALUATION FORM

HOSPITAL:	PATIENT NUMBER:	WARD:
NAME	SEX: M F AGE:	ASA (Inquire) 1 2 3 4 5 E
OPERATION:	DIAGNOSIS/ASSESSMENT:	SURGEON:

Yes No	Study consent Obtained	Yes No	Pre-op interview by anesthetist observed or documented	Yes No	Anesthesia consent obtained

Is patient NPO? (Inquire)	YES or NO
Planned/ emergency procedure? (Inquire)	PLANNED or EMERGENCY
Date of last menstrual period (women only)	☐ Not documented
Allergies	☐ Not documented
Medications	☐ Not documented
Medical Conditions	☐ Not documented
Social hx	☐ Not documented
Lab Data	☐ None
EKG Done?	YES or NO
Chest Xray done?	YES or NO
Anticipated challenges	☐ Not written or discussed
Patient identified at start of surgery?	☐ Patient name spoken out loud by surgeon, anesthetist or nurse to confirm patient identity ☐ Name card attached to patient gown ☐ Not identified

ANESTHESIA PLAN (Check all that apply)

TYPE OF ANESTHESIA	Yes
General Anesthesia	
Total Intravenous Anesthesia (TIVA)	
Inhalational (+ Intravenous)	
Regional Anesthesia	
• Spinal	
• Epidural	
• Nerve block	
Local anesthesia	
Monitored Anesthesia Care	

PREOPERATIVE VITAL SIGNS

BLOOD PRESSURE:

PULSE:

SaO2:

RESPIRATION:

NONE RECORDED ☐

_____ RA's Initials

APPENDIX 1 (*Continued*)

HOSPITAL:

DATE:

JOHNS HOPKINS MEDICINE

PATIENT #: _____

LAST NAME: _____

OBSERVATIONAL PHASE

Time											TOTAL
Oxygen L/min											
Nitrous Oxide L/min											
Halothane/ Isoflurane %											
Fentanyl (mcg)											
Diazepam/ Midazolam (mg)											
Propofol/Diprivan (mg)											
Ketamine (mg)											
Bupivacaine (mg)											
Fluids (mL)											
Normal Saline											
Ringers Lactate											
Blood											
Other											
Est. Blood Loss (mL)											

mmHg

V Systolic BP
^ Diastolic BP

200

X Pulse
o Fetal Heart Rate
P Power failure

150

100

50

SaO,
ETCO2
Breaths/min

NOTES:

TIME

Anesthesia Start time:

Induction Time:

Antibiotic time:

Surgery Start time:

Surgery stop time:

Anesthesia Stop Time

Position of patient:

At time of incision
 # total people in theater:
 # Anesthetists in theater:

CRITICAL EVENTS:
1. ***Baby**: Alive Dead
2. ***APGAR score:**

NOTES:

MONITORS USED:

BP Cuff	yes	no
Pulse oximeter	yes	no
ECG	yes	no
Temperature	yes	no
ETCO2	yes	no
Fetal heart monitor (laboring women only)	yes	no

Oxygen source: ☐ Oxygen tank ☐ Room air ☐ Concentrator

Anesthesia Machine Used:
☐ Glostavent
☐ Compact-3 (Connaught)
☐ Other Connaught (specifiy)
☐ Other PCMH (specify)
☐ Ambubag
☐ None

Anesthetist:

Phone number:

Data collector:

POST OP

Time AM PM

☐ Recovery Room
☐ Intensive Care Unit (ICU)
☐ Home
☐ General Ward
☐ Corridor

SaO, P. R. BP T.

OBSERVATIONAL PHASE

ANESTHESIA RECORD

POST OPERATIVE

DATE: _____ TIME: _____ PATIENT NUMBER:_____

Ask the anesthetist : Did they observe

1. Bronchospasm?	YES NO	Not GA case
2. Laryngospasm?	YES NO	Not GA case
3. Number of times intubation attempted?	1 2 3 4 5+	Not GA case

Research assistants: Did you observe

1. Vomiting?	YES NO	
2. Electrical power failure?	YES NO	If yes, #of minutes: _____
3. Anesthesia machine malfunction?	YES NO	If yes, #of minutes: _____
4. Monitoring equipment malfunction? (Circle what malfunctioned): Pulse ox BP cuff Entire monitor	YES NO	If yes, #of minutes: _____

TYPE OF ANESTHESIA INTRAOP (Check all that apply)

General Anesthesia		Regional Anesthesia	
Total Intravenous Anesthesia		• Spinal	
Inhalational (+intravenous)		• Epidural	
• Mask		• Nerve block	
• Oral airway		Regional Anesthesia changed to GA **(give reason)**	
• Endotracheal tube (ETT)		Local anesthesia	
• Laryngeal Mask Airway		Monitored Anesthesia Care	

POST OPERATIVE STATUS

PATIENT'S STATUS

Level of consciousness	Awake	
	Arousable	
	Asleep	
Airway	Spontaneous	
	Assisted	
	Controlled	
Apparent Pain level	None	
	Mild	
	Moderate	
	Severe	

MONITORS

Blood pressure	
Pulse Oximeter	
EKG	
Capnography	
NONE	

OXYGEN SOURCE

Concentrator	
Oxygen tank	
Room air	

_____

RA's initials

DISCLOSURES

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Attestation: Rahul Koka has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
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