Providing Anesthesia Care in Resource-limited Settings

A 6-year Analysis of Anesthesia Services Provided at Médecins Sans Frontières Facilities

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ABSTRACT

Background: Anesthesia is integral to improving surgical care in low-resource settings. Anesthesia providers who work in these areas should be familiar with the particularities associated with providing care in these settings, including the types and outcomes of commonly performed anesthetic procedures.

Methods: The authors conducted a retrospective analysis of anesthetic procedures performed at Médecins Sans Frontières facilities from July 2008 to June 2014. The authors collected data on patient demographics, procedural characteristics, and patient outcome. The factors associated with perioperative mortality were analyzed.

Results: Over the 6-yr period, 75,536 anesthetics were provided to adult patients. The most common anesthesia techniques were spinal anesthesia (45.56%) and general anesthesia without intubation (33.85%). Overall perioperative mortality was 0.25%. Emergent procedures (0.41%; adjusted odds ratio [AOR], 15.86; 95% CI, 2.14 to 115.58), specialized surgeries (2.74%; AOR, 3.82; 95% CI, 1.27 to 11.47), and surgical duration more than 6 h (9.76%; AOR, 4.02; 95% CI, 1.09 to 14.88) were associated with higher odds of mortality than elective surgeries, minor surgeries, and surgical duration less than 1 h, respectively. Compared with general anesthesia with intubation, spinal anesthesia, regional anesthesia, and general anesthesia without intubation were associated with lower perioperative mortality rates of 0.04% (AOR, 0.10; 95% CI, 0.05 to 0.18), 0.06% (AOR, 0.26; 95% CI, 0.08 to 0.92), and 0.14% (AOR, 0.29; 95% CI, 0.18 to 0.45), respectively.

Conclusions: A wide range of anesthetics can be carried out safely in resource-limited settings. Providers need to be aware of the potential risks and the outcomes associated with anesthesia administration in these settings. **(ANESTHESIOLOGY 2016; 124:561-9)**

THE global burden of surgical disease is significant and increasing. Of more than 230 million surgical procedures performed annually, only approximately 8.1 million (3.5%) procedures take place in the poorest one third of the world's population.[1,2] More than two billion people in low-income settings have minimal access to emergency and essential surgical services, and those with access are often exposed to unsafe anesthesia care.[3,4] However, data suggest that surgically treatable conditions account for up to a quarter of the global disease burden.[5,6] Global attention to this gross disparity is growing, with calls to prioritize essential surgical interventions as an integral and cost-effective target of the Post-2015 Development Agenda.[7]

Current definitions of global surgery highlight the multidisciplinary nature of the effort required to provide surgical care.[8] Anesthesia providers are indispensable in the efforts to address the burden of global surgical disease. The marked

What We Already Know about This Topic

- There is a severe shortage of trained anesthesia providers in low- and middle-income countries
- Inadequate resources, including equipment and drug choices, often lead to less than ideal circumstances for the practice of safe and effective anesthesia

What This Article Tells Us That Is New

- Médecins Sans Frontières (MSF; Doctors Without Borders) anesthesia providers include physician anesthesiologists, nurse anesthetists, and local nurses trained by MSF to provide anesthesia
- A standardized set of essential equipment and medications is provided for each mission to enable anesthesia care delivery and management of potential complications
- A retrospective review of anesthetic procedures performed at MSF facilities from 2008 until 2014 found that a wide range of anesthesia procedures can be carried out safely in resource-limited settings with resources such as those provided by MSF

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shortage of trained anesthesia providers in low- and middle-income countries (LMICs) is tremendous, with numbers often one hundredth than in high-income countries. For example, countries like Côte d'Ivoire have an estimated anesthesiologist-to-patient ratio of 0.17:100,000, a value that is substantially lower than that of the United States, which has an estimated 25 anesthesia providers to 100,000 patients, or the United Kingdom, which has approximately 20 physician anesthetists to 100,000 patients.[3] Moreover, the practice of anesthesia in LMICs is often far from typical. Insufficient personnel, training, drug choices, equipment, and intensive care beds often lead to less than ideal circumstances, calling for creativity in delivering care in these settings.

A variety of approaches have been suggested to help address the gap in surgical care in LMICs. Suggestions include strengthening the local health system *via* partnership programs; developing local capacity by training more clinicians while incentivizing their local retention; and continuing to have international organizations provide surgical care in areas with minimal infrastructure. Given the inherent lag associated with health system strengthening and local capacity development, the need for international organizations to address the immediate gap is great.

This article is featured in "This Month in Anesthesiology," page 1A. Corresponding article on page 521. This article has an audio podcast. Drs. Ariyo, Trelles, Wong, Kushner, and Latif were responsible for the study design and conception. Dr. Trelles, Helmand, Amir, Hassani, Mftavyanka, Nzeyimana, Akemani, Ntawukiruwabo, Drs. Charles and Yana, Moussa, Kamal, Suma, M. Ahmed, and M. Abdullahi acquired and checked the data. Drs. Ariyo, Trelles, Kushner, and Latif analyzed and interpreted the data. Drs. Ariyo, Trelles, and Latif were responsible for writing the manuscript. All authors commented on and critically revised the manuscript.

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Médecins Sans Frontières (MSF, also known as Doctors Without Borders) is an international medical humanitarian organization that "delivers emergency aid to people in places affected by armed conflict, epidemics, natural disasters and exclusion from healthcare…." MSF has more than 40 yr of experience in providing surgical care to over 70 countries around the world through its five operational centers.[9] Surgeons, obstetricians, and anesthesiologists from all over the world are recruited as part of the surgical staff for the various missions. MSF is invested in both direct patient care and the training of local workers to build capacity and ensure sustainability of effective care.

The goal of this study was to review the anesthesia care provided by various missions coordinated by the MSF Operational Center Brussels (MSF-OCB) between 2008 and 2014 and to ascertain the types and outcomes of commonly performed anesthetic techniques. This information is essential in determining what anesthesia equipment and expertise are required to address the immediate global burden of surgical disease in the low-resource settings of LMICs.

Materials and Methods

The study included 45 surgical missions conducted by MSF-OCB in 21 countries between July 2008 and June 2014 (fig. 1).

Operative Setting

All procedures were conducted with the permission of local health authorities in either government hospitals or local MSF facilities. MSF missions followed strict guidelines when implementing the projects. All sites had electricity, clean water, operating rooms, postanesthesia recovery rooms, and postsurgical wards. Oxygen supply and pulse oximetry were considered essential and were available at all MSF operative locations. A standardized set of equipment and medications was provided for each mission to enable anesthesia care delivery and management of potential complications (appendix).

Anesthesia Providers

MSF anesthesia providers included nurse anesthetists and physician anesthesiologists who ranged from resident physicians with at least 3 yr of clinical training to independently licensed physicians. Local nurses were also trained by MSF to provide anesthesia, although they always worked under the supervision of the expatriate providers during the missions. None of these providers were required to have prior experience working in austere environments. Anesthesia providers provided perioperative care for all patients, from the preoperative evaluation through the intraoperative period, until they achieved adequate recovery and pain control in the postoperative period. All care was provided free of charge.

Data Collection and Organization

For all missions, a standardized data collection form was used to record data from all operative procedures performed at MSF-OCB facilities worldwide. Data were recorded in

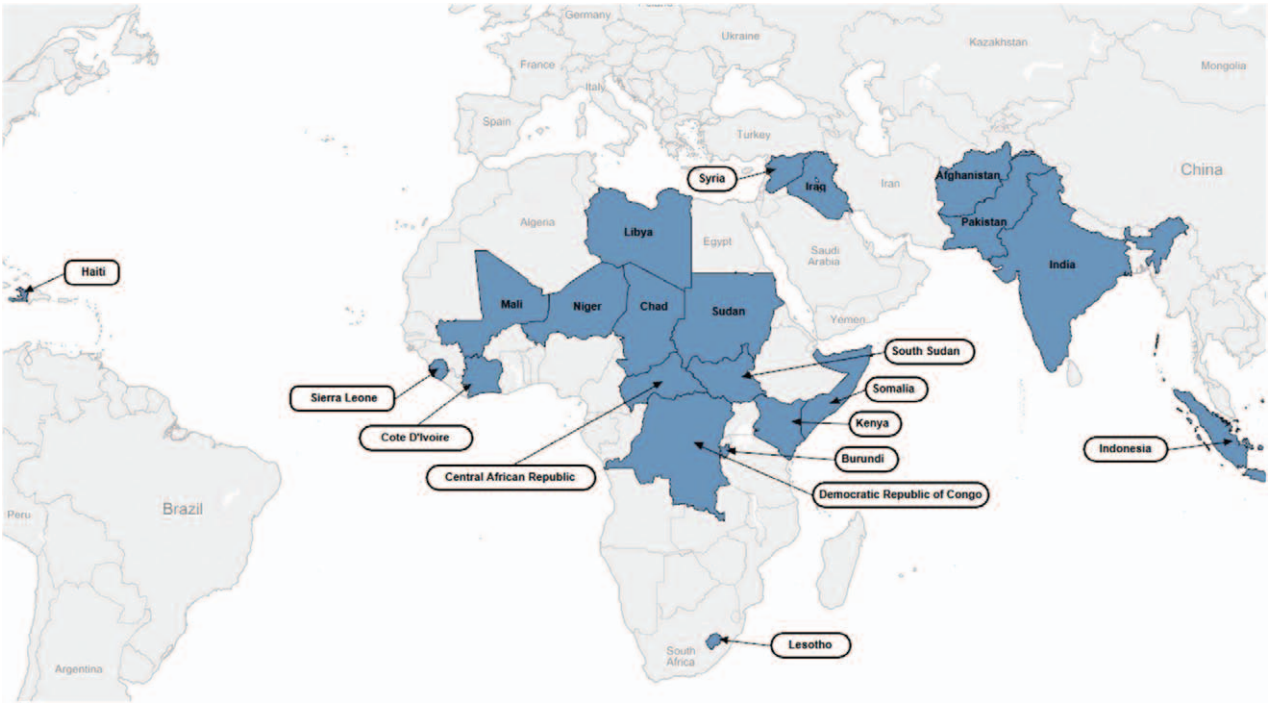

Fig. 1. Countries in which Médecins Sans Frontières–Operational Centre Brussels missions provided anesthesia care between 2008 and 2014.

a logbook by the MSF anesthesia providers and then transcribed monthly into an electronic database (Excel; Microsoft, USA). The electronic database was then transmitted to the MSF-OCB headquarters in Brussels, where it was promptly reviewed for completeness and accuracy by the heads of the surgical, anesthesia, gynecology, and emergency medicine units. Discrepancies were addressed by contacting appropriate program personnel involved in data entry.

Baseline patient characteristics, including age (years), sex, and American Society of Anesthesiologists physical status (ASA-PS) classification, were included in the analysis. The urgency of the procedure was categorized into emergent cases, which were defined as acute emergencies such as hemostatic hysterectomy; time-sensitive cases, which could be delayed for a few days but must imperatively be performed; and elective cases, which could be scheduled at convenience. Age was categorized into 25-yr groups from 15 yr to greater than 65 yr of age (15 to 40, 40 to 65, and greater than 65 yr). The 37 surgical procedures performed were categorized into 6 groups: minor surgery, wound surgery, visceral surgery, orthopedics, gynecology/obstetrics and urology, and specialized surgery (table 1). Operating room times were grouped into four categories: procedures less than 1 h, 1 to 3 h, 3 to 6 h and more than 6 h. Anesthesia types were classified as general anesthesia with intubation (with or without muscle relaxation); general anesthesia without intubation or muscle relaxation; spinal anesthesia; regional anesthesia with block of a nerve or plexus, including intravenous regional anesthesia or Bier Block; combined anesthesia, which included a combination of techniques such as spinal anesthesia with sedation or general anesthesia; and other anesthesia. Perioperative mortality was defined as death in the operating room (during either anesthesia induction or surgical intervention) or death in the immediate recovery period, which was defined as time after the surgical procedure in a recovery room during which the patient was still under the care of an anesthesia provider.

Statistical Analysis

Descriptive analyses of baseline characteristics were reported as frequencies. Each potential confounder was analyzed for its relationship with the outcome in separate logistic regression models. Variables with an association of $P < 0.20$ were included in a multiple logistic regression model for evaluation of their relationship with perioperative mortality. An odds ratio with a $P < 0.05$ was considered statistically significant in the final model. Evaluation of variance inflation factor was used to confirm that multicollinearity was absent in the final model. Several multivariate models were considered, with the most parsimonious model as supported by the lowest Akaike information criteria being chosen. A total of 4.85% of the records had some element of missing data. A sensitivity analysis was performed of the complete dataset, and no differences were found in the significance of the results. Only complete patient records were used for the final analysis. Data were analyzed with Stata 13 (Stata Corporation, USA). This study was reviewed by the MSF Ethical Review Board on December 10, 2014, and satisfied the criteria for ethics exemption as a retrospective review of routinely collected programmatic data.

Table 1. Types of Procedures Performed by Médecins Sans Frontières–Operational Centre Brussels Missions, 2008 to 2014

Group	Types of Procedures
Minor surgery	Simple wound debridement, abscess drainage, circumcision
	Drain insertion, chest tube insertion, dressing change
Gynecology/obstetrics and urology	Cesarean section, complex delivery, episiotomy or perineal laceration repair, tubal ligation, curettage
	Hysterectomy, oophorectomy, tumor resection (pelvic)
	Obstetric fistula repair
	Urological procedures
Orthopedics	Fracture reduction
	External fixation
	Limb amputation
	Internal fixation
	Internal fixation removal
	Curettage for osteomyelitis
	Joint procedure
	Bone graft
	Nerve repair
	Other (corrective procedure)
Specialized surgery	Craniectomy
	Vascular repair
	Reconstructive surgery for contractures
	Thoracotomy
	Tracheotomy
	Ophthalmological procedure
	Maxillofacial surgery
Visceral surgery	Hernia repair, other anogenital
	Exploratory laparotomy
	Bowel resection and repair
	Repair or resection of solid viscous (spleen, liver, kidney)
	Tumor resection (breast, thyroid)
Wound surgery	Burn dressings
	Extensive debridement (including fasciotomy, digit amputation)
	Skin or muscle graft surgery
	Foreign body removal

Results

Between July 2008 and June 2014, MSF-OCB performed 79,383 anesthetics on patients aged 15 yr or older in 21 different countries. Of the 75,536 patients whose records were complete, 28,590 (37.85%) were male and 46,946 (62.15%) were female. The majority of patients were younger than 35 yr. Most patients, 44,717 (59.20%), were ASA-PS class I category; 26,172 (34.65%) were ASA-PS class II; and 3,850 (5.10%) were ASA-PS class III. Of these surgical cases, 10,062 (13.31%) were considered to be elective, 22,651 (30.0%) were time sensitive, and 42,823 (56.69%) were emergent (table 2).

The most common type of anesthetic technique was spinal anesthesia (34,413 [45.56%]); general anesthesia without intubation or muscle relaxation (25,566 [33.85%]) was the second most common (table 3). The most common type of procedure performed was cesarean section (26,091 [34.54%]). Other common procedure types included

Table 2. Patient and Surgical Characteristics and Associated Mortality Rates

Category	Total (%), N = 75,536	Perioperative Death, N (% within Category)
Sex		
Male	28,590 (37.85)	85 (0.30)
Female	46,946 (62.15)	103 (0.22)
Age category (yr)		
15–24	24,465 (32.39)	49 (0.20)
25–34	25.802 (34.16)	69 (0.27)
35–44	13,594 (18.00)	51 (0.38)
45–54	5,481 (7.26)	10 (0.18)
55–64	3,426 (4.54)	3 (0.09)
65+	2,768 (3.66)	6 (0.22)
ASA-PS classification		
ASA-PS I	44,717 (59.20)	28 (0.06)
ASA-PS II	26,172 (34.65)	27 (0.10)
ASA-PS III	3,850 (5.10)	39 (1.01)
ASA-PS IV	711 (0.94)	61 (8.58)
ASA-PS V	86 (0.11)	33 (38.37)
Surgical urgency		
Elective	10,062 (13.32)	1 (0.01)
Time sensitive	22,651 (30)	10 (0.04)
Emergent	42,823 (56.69)	177 (0.41)

ASA-PS = American Society of Anesthesiologists physical status classification.

wound surgeries (18,547 [24.55%]), herniorrhaphies (5,622 [7.44%]), and minor surgical procedures such as chest tube and other drain placement (3,242 [4.29%]).

When looked at by surgical group, general anesthesia without intubation was most commonly administered for minor surgery (6,974 [64.51%]) and wound surgery (7,796 [70.98%]). Spinal anesthesia was most commonly used for obstetric/gynecologic and urologic procedures (23,671 [69.45%]), orthopedic procedures (2,925 [39.21%]), and visceral procedures (5,723 [48.51%]). Regional anesthesia was the most prevalent anesthetic in specialized surgery (161 [40.05%]; table 4).

Overall perioperative mortality was calculated to be 0.25%. On multiple logistic regression, no significant relationship was noted between perioperative mortality and age or sex. The adjusted odds ratio (AOR) of perioperative mortality was higher in patients who were in higher ASA-PS categories. The AOR was 5.25 (95% CI, 3.10 to 8.85) for ASA-PS class III, 35.32 (95% CI, 21.32 to 58.50) for ASA-PS class IV, and 226.25 (95% CI, 120.30 to 424.96) for ASA-PS class V, compared with ASA-PS class I. Emergent cases had higher odds of perioperative mortality than did planned cases (AOR, 15.86; 95% CI, 2.14 to 115.58), and specialized surgery had higher odds of perioperative mortality than did minor surgery (AOR, 3.82; 95% CI, 1.27 to 11.47). Operative times of greater than 6 h had a higher odds of perioperative mortality than did cases lasting under an hour (AOR, 4.02; 95% CI, 1.09 to 14.88). Spinal anesthesia (AOR, 0.10; 95% CI, 0.05 to 0.18), regional anesthesia

Table 3. Surgical and Anesthesia Categories with Average Operating Room Duration

Category	Total (%), N =75,536	Mean Operating Room Time (min)	Perioperative Deaths (%)
Anesthesia type			
General anesthesia with tracheal intubation	7,653 (10.13)	107	129 (1.69)
General anesthesia without tracheal intubation	25,566 (33.85)	50	35 (0.14)
Spinal anesthesia	34,413 (45.56)	74	14 (0.04)
Regional anesthesia	5,220 (6.91)	36	3 (0.06)
Combined anesthesia	2,291 (3.03)	90	6 (0.26)
Other anesthesia	393 (0.52)	33	1 (0.25)
Surgery type			
Minor surgery	10,810 (14.31)	39	8 (0.07)
Obstetrics/gynecology and urology	34,083 (45.12)	71	72 (0.21)
Orthopedics	7,460 (9.88)	87	5 (0.07)
Specialized surgery	402 (0.53)	83	11 (2.74)
Visceral surgery	11,797 (15.62)	86	85 (0.72)
Wound surgery	10,984 (14.54)	49	7 (0.06)

Table 4. Surgical Categories and Associated Anesthesia Procedures

Surgery Type	Total (%)	General Anesthesia with Intubation (%)	General Anesthesia without Intubation (%)	Spinal Anesthesia (%)	Regional Anesthesia (%)	Combined Anesthesia (%)	Other Anesthesia (%)
Minor surgery	10,810 (14.31)	233 (2.16)	6,974 (64.51)	831 (7.69)	2,512 (23.24)	102 (0.94)	158 (1.46)
Obstetrics/gynecology and urology	34,083 (45.12)	2,249 (6.60)	6,383 (18.73)	23,671 (69.45)	464 (1.36)	1,197 (3.51)	119 (0.35)
Orthopedics	7,460 (9.88)	900 (12.06)	2,753 (36.90)	2,925 (39.21)	598 (8.02)	245 (3.28)	39 (0.52)
Specialized surgery	402 (0.53)	129 (32.09)	85 (21.14)	18 (4.48)	161 (40.05)	8 (1.99)	1 (0.25)
Visceral surgery	11,797 (15.62)	3,669 (31.10)	1,575 (13.35)	5,723 (48.51)	248 (2.10)	573 (4.86)	9 (0.08)
Wound surgery	10,984 (14.54)	473 (4.31)	7,796 (70.98)	1,245 (11.33)	1,237 (11.26)	166 (1.51)	67 (0.61)

(AOR, 0.26; 95% CI, 0.08 to 0.92), and general anesthesia without intubation (AOR, 0.29; 95% CI, 0.18 to 0.45) were associated with a statistically significant lower odds of perioperative death when compared with general anesthesia with intubation (table 5).

Discussion

This study provides insight into the types of anesthesia services needed in LMICs and their outcomes. The infrastructure of hospitals and operating rooms found in LMICs is often underdeveloped, with unreliable supplies of oxygen and a lack of functioning anesthesia machines, scavenging systems, and appropriate laryngoscopes and endotracheal tubes. These limitations constitute a major handicap for a field that is heavily reliant on technology, which may make it difficult to provide safe and effective anesthesia. With such deficiencies in resources for patient care, streamlining and standardizing care and equipment become even more crucial to help maintain quality of care and consistently achieve good outcomes. Our study of anesthetic procedures provided at MSF facilities demonstrates that a wide range of anesthetic procedures can be carried out safely and effectively in resource limited settings. For example, anesthesia at MSF was standardized to a simple list of anesthesia medications: thiopental and ketamine for general anesthesia without intubation; halothane for general anesthesia with intubation; 0.5% hyperbaric bupivacaine for spinal anesthesia; and levobupivacaine for regional anesthesia. This shows that under strict guidelines and protocols, such as those utilized in the MSF model (appendix), good outcomes can be achieved even in resource-limited settings.

The high burden of obstetric anesthesia deserves particular attention, especially given the unacceptably high obstetric morbidity and mortality in low-resource settings. The World Health Organization (WHO) estimated that more than 90% of maternal deaths are in resource-poor countries and concluded that poor access to emergency obstetric services was one of the leading causes.[10,11] Previous studies have shown that maternal care is associated with greater medical needs than are trauma or other medical conditions, especially during times of conflict and in resource-poor regions.[12,13] This discrepancy is partially due to the need to have the capacity for surgical intervention. International humanitarian organizations such as MSF are helping to meet these needs in an effective manner. A 2012 review of MSF operations in Sub-Saharan Africa showed cesarean section rates to be

Table 5. Factors Associated with Perioperative Mortality in Surgical Procedures Performed by Médecins Sans Frontières–Operational Centre Brussels Missions, 2008 to 2014

Variable	Unadjusted Odds Ratio	*P* Value	Adjusted Odds Ratio	*P* Value
Sex				
Female	1.0 (reference)			
Male	1.43 (1.08–1.90)	0.01	0.99 (0.63–1.57)	0.98
Age (yr)				
15–40	1.0 (reference)			
41–65	0.63 (0.39–1.02)	0.06	0.64 (0.38–1.09)	0.10
> 65	0.66 (0.25–1.79)	0.42	0.50 (0.17–1.45)	0.20
ASA classification				
ASA-PS class I	1.0 (reference)			
ASA-PS class II	1.60 (0.95–2.70)	0.08	1.26 (0.73–2.14)	0.40
ASA-PS class III	15.82 (9.78–25.53)	< 0.01	5.25 (3.10–8.85)	< 0.01
ASA-PS class IV	147.73 (94.35–230.44)	< 0.01	35.32 (21.32–58.50)	< 0.01
ASA-PS class V	964.36 (544.57–1,685.80)	< 0.01	226.25 (120.30–424.96)	< 0.01
Surgery type				
Minor surgery	1.0 (reference)			
Obstetrics/gynecology and urology	3.01 (1.45–6.25)	< 0.01	1.19 (0.48–2.94)	0.71
Orthopedics	1.11 (0.39–3.22)	0.84	0.74 (0.23–2.36)	0.62
Specialized surgery	39.33 (15.72–98.29)	< 0.01	3.82 (1.27–11.47)	0.02
Visceral surgery	10.77 (5.20–22.22)	< 0.01	1.85 (0.79–4.35)	0.16
Wound surgery	0.96 (0.37–2.60)	0.96	0.66 (0.23–1.88)	0.44
Urgency				
Elective	1.0 (reference)			
Emergent	45.03 (6.31–321.18)	< 0.01	15.86 (2.14–115.58)	0.01
Time sensitive	4.42 (0.57–34.47)	0.16	4.52 (0.57–36.23)	0.16
Duration of surgery (min)				
0–60	1.0 (reference)			
60–180	1.85 (1.34–2.56)	< 0.01	0.74 (0.52–1.06)	0.10
180–360	12.10 (7.85–18.54)	< 0.01	1.34 (0.79–2.27)	0.28
> 360	62.38 (21.76–179.47)	< 0.01	4.02 (1.09–14.88)	0.04
Anesthesia type				
General anesthesia with intubation	1.0 (reference)			
General anesthesia without intubation	0.08 (0.07–0.34)	< 0.01	0.29 (0.18–0.45)	< 0.01
Spinal anesthesia	0.02 (0.01–0.04)	< 0.01	0.10 (0.05–0.18)	< 0.01
Regional anesthesia	0.03 (0.01–0.10)	< 0.01	0.26 (0.08–0.92)	0.04
Combined anesthesia	0.15 (0.07–0.34)	< 0.01	0.44 (0.19–1.05)	0.06
Other anesthesia	0.15 (0.02–1.04)	0.06	0.53 (0.06–4.57)	0.57

Multivariate model adjusted for patient sex, age, ASA-PS classification, type of surgery, surgical urgency, duration of surgery, and type of anesthesia.
ASA-PS = American Society of Anesthesiologists physical status classification.

approximately 6.2%, which meets the threshold that has been recommended by the WHO for improved maternal outcomes.[14,15]

Our results showed that spinal anesthesia was the most commonly used anesthetic technique overall. It was also one of the safest, having significantly lower adjusted odds of death than general anesthesia requiring intubation. The popularity of spinal anesthesia in these settings is likely due to its safety profile, efficacy in providing surgical anesthesia, and minimal equipment requirements, as patients do not need airway manipulation or ventilator support. In a review of randomized trials, Rodgers *et al.*[16] reported lower perioperative mortality with spinal and epidural anesthetics than with general anesthesia. Other smaller studies have reported high satisfaction and low complication rates when spinal anesthetics are used in low-resource settings.[17] Especially with large numbers of cesarean sections, the use of spinal anesthesia enables anesthetists to provide safe anesthesia; avoid airway manipulation; and decrease the risk of aspiration, desaturations, and death that may be associated with general anesthesia. For example, Enohumah and Imarengiaye[18] studied more than 12,000 maternal deliveries that included over 2,000 cesarean sections in Nigeria. Six of the 84 deaths were linked solely to anesthesia, with issues such as failed airway and insufficient monitoring associated with general anesthetics. In addition, spinal anesthesia is useful in settings with limited infrastructure for postoperative care because it allows rapid hospital discharge after procedures.

General anesthesia without intubation was the second most common type of anesthesia, being frequently used for minor and wound surgeries. It was also a common option for orthopedic, specialized, and even obstetric/gynecologic and

urologic surgeries. The adjusted odds of death for general anesthesia without intubation were one third of those with general anesthesia plus intubation. This improved outcome can be potentially attributed to the wide use of ketamine in these operations. Ketamine provides surgical anesthesia and analgesia, allows maintenance of spontaneous respiration, and maintains or augments blood pressure. All of these attributes are useful when providing anesthesia to hypovolemic patients, such as those with trauma and sepsis, and to obstetric patients and other patient populations at high risk for difficult airway. This ability to provide general anesthesia in a spontaneously breathing patient is invaluable in LMICs, as, in most cases, it minimizes the need for equipment more elaborate than a pulse oximeter and sphygmomanometer.[19,20] However, MSF providers were still able to provide general anesthesia with intubation and/or muscle relaxation when such techniques were imperative to safety and successful surgery. It is noteworthy that regional anesthetic techniques were used in only 6.9% of cases despite the favorable safety profile and the relatively minimal infrastructure needed in terms of equipment and medications. Its use is probably limited by the need for a proficient level of expertise to perform them effectively, an area of potential future focus.[21]

Perioperative mortality in our population was approximately 0.25%, a number comparable with that in the existing literature. The best data available are from a systematic review and meta-analysis by Bainbridge *et al.*,[22] who reported a perioperative mortality of 2,445 per million (0.24%) in developing countries in the 1990s to 2000s. Nunnally *et al.*[23] reported on 555 deaths in the operating room or recovery area from 1.6 million anesthetics (27 practices and 156 facilities) in the US National Anesthesia Clinical Outcomes Registry, giving a rate of 0.03%. As in the previous studies, we found that higher ASA-PS status and emergency procedures were associated with higher mortality.[24,25] Interestingly, age was not significantly associated with perioperative mortality after adjusting for the ASA-PS status. Specialized surgery represents a set of procedures that are more complex and performed least frequently at MSF operations. Such surgeries were associated with higher mortality in this cohort, possibly because of their low volume and the relative lack of expertise among practitioners in safely performing these procedures.[26,27] However, there is a need to evaluate the quality of surgical services provided by humanitarian missions. Although an ideal model for assessing quality care is challenging, using a combination of structural, process, and outcome measures has been suggested.[28] Regulation through recruitment of qualified surgical and anesthesia staff, establishment of protocols for perioperative practices, and standardized data collection tools for critical postoperative outcomes can be used to incorporate these measures. Chu *et al.*[29] proposed a humanitarian surgery checklist derived from the WHO safe surgery checklist, which is tailored to humanitarian surgery settings. Their hope is to achieve similar trends in mortality reduction.[29,30]

Keeping the delivery of anesthesia care simple in low-resource settings is essential to facilitate the efficacy, safety, and sustainability of surgical missions. Anesthetics are streamlined to a basic and conservative list of drugs and procedures that are sustainable, can be taught efficiently, and are minimally prone to errors. As noted in the previous publications of MSF work, local staff are trained to address the immediate gap in surgical care during times of crisis.[31] In addition, through a focused curriculum, they are equipped with skills to become local resources for continued care in their communities long after mission completion.

This unique analysis describes a large number of anesthesia procedures in a variety of low-resource settings. The anesthesia care was standardized in terms of techniques and medication. Both anesthesiologists and nonphysician anesthesia providers were involved in these missions, a fact that is relevant given the paucity of physician anesthesiologists in LMICs. This study provides information that can be used to help other organizations design similar projects and to help build capacities for local operations. One possible limitation is that these operations were mostly in emergency situations and, therefore, may not be generalizable to the chronic needs of LMICs that are not in crisis. However, some of the MSF missions were in nonconflict settings, and MSF invested in the training of local workers for continued practice of anesthesia care in postconflict times.[30] Another limitation of this study is the lack of data on the exact cause of mortality, which would have been helpful in identifying specific anesthetic or surgical complications and shortcomings in this type of setting. We also have mortality data only on patients who died in the hospital; thus, we might have missed those who died at home after discharge. There is clearly a need for an inclusive standardized dataset, a need that MSF is trying to address by expanding its data collection efforts. Similarly, the Anesthesia Quality Institute is working to establish a large and unified database for nongovernmental organizations that provide anesthesia care in low-resource settings. The ultimate aim should be to establish a large repertoire of data that may help providers evaluate and improve quality of care, patient safety, and outcomes in these settings.

In conclusion, delivery of anesthesia is crucial to realizing the goal of improving global surgical services. With the dearth of anesthesia providers in LMICs, humanitarian missions provided by international organizations such as MSF are absolutely necessary. They must be adaptable in caring for a variety of age groups and surgical conditions. Provision of safe care and good outcomes is possible. Providers must be flexible in their anesthesia practice and not too reliant on technology or drug variety, to deliver safe and effective care in these low-resource settings.

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Competing Interests

Dr. Latif is a founding partner and equity holder in Patient Doctor Technologies, Inc. (Sunnyvale, California), which owns and operates the website www.doctella.com. The other authors declare no competing interests.

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Appendix: Essential Equipment and Medications Used by Médecins Sans Frontières Missions

- Essential equipment (with spare parts) per occupied operating room
  - Oxygen source: Oxygen concentrator or oxygen cylinder with manometers
  - Intubation material
    - Laryngoscope sets
    - Stiff or gum elastic bougie (sterile)
    - Magill forceps (2 sizes)
  - Resuscitation (self-inflating) bag with accessory balloon, adult and pediatric self-inflating bags
  - A pressure infusion bag
  - Aspiration device
  - Monitoring equipment
    - Stethoscope
    - Pulse oximeter (with spare transducer)
    - Sphygmomanometers (adult, child, and neonate cuffs)
  - Several catheter mounts to increase mobility at the patient end of the circuit
- Essential disposable equipment
  - Endotracheal tubes with appropriate connectors
  - Oral airways
  - Oxygen tubes
  - Anesthesia masks
  - Aspiration tubes
  - Nasogastric tubes
  - Pleural drainage tubes
  - Bladder catheters and urinary bags
  - Batteries for laryngoscope and pulse oximeters
  - Survival blankets
  - Tracheotomy tubes
  - Breathing circuit filters
  - Intravenous catheters, needles, syringes of multiple sizes
  - Infusion "Y" sets
  - Spinal needles (multiple sizes)
  - Electrocardiogram sticker electrodes (optional for selected missions)
- Essential drugs for anesthesia management
  - Sedatives: Midazolam
  - Hypnotics: Thiopental, ketamine, halothane
  - Analgesics: Morphine, fentanyl, paracetamol, NSAIDs (ibuprofen and diclofenac), tramadol, and codeine
  - Opioid antagonist: naloxone
  - Neuromuscular relaxants/reversal: Succinylcholine, vecuronium, atracurium, neostigmine
  - Local anesthetics: Lidocaine, hyperbaric bupivacaine, levobupivacaine
  - Intravenous fluids: Normal saline, lactate Ringer's solution, 5% glucose, 10% glucose, Haemaccel®, Plasmion®
  - Antibiotics: Amoxicillin + clavulanic acid, cefazolin, ceftriaxone, gentamicin, metronidazole
  - Vasoactive medications: Epinephrine (adrenaline), ephedrine, atropine, hydralazine
  - Dexamethasone and hydrocortisone
  - Oxytocin and ergometrine
  - Hyoscine, metoclopramide, promethazine, and omeprazole
  - Others: Dextrose, calcium gluconate, potassium chloride, sodium bicarbonate, magnesium sulfate, furosemide, salbutamol

NSAIDs = nonsteroidal antiinflammatory drugs.