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Rwandan Surgical and Anesthesia Infrastructure: A Survey of District Hospitals

Michelle R. Notrica · Faye M. Evans · Lisa Marie Knowlton · K. A. Kelly McQueen

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Abstract
Background In low-income countries, unmet surgical needs lead to a high incidence of death. Information on the incidence and safety of current surgical care in low-income countries is limited by the paucity of data in the literature. The aim of this survey was to assess the surgical and anesthesia infrastructure in Rwanda as part of a larger study examining surgical and anesthesia capacity in low-income African countries.
Methods A comprehensive survey tool was developed to assess the physical infrastructure of operative facilities, education and training for surgical and anesthesia providers, and equipment and medications at district-level hospitals in sub-Saharan Africa. The survey was administered at 21 district hospitals in Rwanda using convenience sampling.
Results There are only nine Rwandan anesthesiologists and 17 Rwandan surgeons providing surgical care for a population of more than 10 million. The specialty-trained Rwandan surgeons and anesthesiologists are practicing almost exclusively at referral hospitals, leaving surgical care at district hospitals to the general practice physicians and nurses. All of the district hospitals reported some lack of surgical infrastructure including limited access to oxygen, anesthesia equipment and medications, monitoring equipment, and trained personnel.
Conclusions This survey provides strong evidence of the need for continued development of emergency and essential surgical services at district hospitals in Rwanda to improve health care and to comply with World Health Organization recommendations. It has identified serious deficiencies in both financial and human resources—areas where the international community can play a role.

M. R. Notrica (✉)
Johns Hopkins Bloomberg School of Public Health,
Baltimore, MD, USA
e-mail: mnotrica@cox.net

F. M. Evans
Emory University School of Medicine and Children's Healthcare of Atlanta, Atlanta, GA, USA

L. M. Knowlton
Department of General Surgery, University of British Columbia, Vancouver, BC, Canada

L. M. Knowlton · K. A. Kelly McQueen
Harvard Humanitarian Initiative, Boston, MA, USA

K. A. Kelly McQueen
Valley Anesthesiology Consultants, Ltd., Phoenix, AZ, USA

Present Address:
M. R. Notrica
1920 E. Cambridge Avenue, Suite 201, Phoenix 85006, AZ, USA

Introduction

Global surgical volume is reported to be high, with an estimated 234 million surgical procedures performed annually and at least 7 million surgical complications [1]. With every operation performed, it is important to note that more than 2 billion people worldwide do not even have access to surgical treatment [2]. In countries with limited resources such as Rwanda, this potentially high rate of unmet and/or delayed satisfaction of surgical need leads to an even greater rate of disability and death. A significant burden of surgical conditions, including obstetric problems, account for 11% of the world's disability adjusted life

years (DALYs) and are found in low- to middle-income settings [3].

Although the World Health Organization (WHO) tracks the numbers of physicians and other health care providers per country as a public health indicator, they do not report the number of specialists in a country. Many low-income countries have a critical shortage of specialists, especially surgical and anesthesia providers [4]. Along with a lack of access to surgical care and poor infrastructure, this shortage of specialists is a critical component of the unmet surgical need and lack of safe, effective surgical care. Additionally, information on the incidence and safety of current surgical care in low-income countries is limited by the paucity of data in the literature [1]. The aim of this article and survey was to assess surgical and anesthesia infrastructure in Rwanda as part of a larger study examining surgical and anesthesia capacity in low-income African countries.

Country overview

Rwanda is a land-locked country in Central Africa, also known as the "land of a thousand hills" and bordered by Burundi, Democratic Republic of the Congo, Tanzania, and Uganda. Rwanda is a small country, consisting of only 26,338 square kilometers of mountainous terrain encompassing an area slightly smaller than the US state of Maryland. By the most recent 2010 census, the nation's population is 10,746,311 [5]. Rwanda's capital and largest city is Kigali, situated near the geographic center of the nation. Kigali alone has a population of almost one million, making Rwanda the most densely populated country in Africa.

Examining Rwanda today, it is easy to forget that only a decade and a half ago the country suffered from mass violence and genocide, leaving the country and its infrastructure devastated. The health care system collapsed, and the country's population was severely traumatized. In an effort to shift power from a select controlling group to the locally elected representatives in the districts, the government adopted a policy of decentralization and redistricting. Subsequently, the responsibility for health and social services was placed in the hands of the locally elected populations. In January 2006, the federal map of Rwanda was redrawn to merge the former 12 provinces into five large provincial areas, aptly named North, South, East, West, and Kigali Provinces. The provinces are further divided into 30 new administrative districts, where the main municipality in each new district bears the name of the old district (leading to some confusion when comparing published and verbal sources). Under this new administrative structure, previous health districts were incorporated into the new districts as departments of health and social services. Health officials responsible for district-level service delivery and management now report directly to locally elected officials as well as to the Republic of Rwanda Ministry of Health (the "Ministry").

In addition to destruction of the health care system, the 1994 genocide decimated Rwanda's previously fragile economic base. Therefore, Rwanda may be considered a relatively young country with a new constitution signed in 2003. The guiding principle of the current government's strategy in Rwanda is called Vision 2020. One of its goals is aimed at aggressively transforming the country's economy to that of a middle-income country by repositioning Rwanda as a center of trade for the surrounding countries and moving its focus away from agriculture. The World Bank, International Monetary Fund, US Agency for International Development, and multitudes of other donors support Rwanda's economic reforms and development programs.

Despite the government's efforts to stabilize and rehabilitate the country's economy, Rwanda currently remains a low-income country with a gross national product per capita of $1000 [6]. Most of the population in Rwanda still lives below the poverty line of 250 Rwandan francs per day (equivalent to about US $0.40) [7]. Ninety percent of the population is still engaged in subsistence agriculture [8].

As per the WHO, Rwanda's mean life expectancy is 58 years—10 years below the global mean and 5 years below the mean for African nations [9]. Rwanda's maternal mortality rate is 1,300 per 100,000—three times the global mean. The infant mortality rate is 72 per 1,000 live births, about 1.5 times the global mean. The number of physicians is <0.5 per 10,000 population and the number of hospital beds is 0.0017 per 100,000 population, both significantly lower than that of the Americas and the global mean. Rwandan health indicators compared to those for Africa, the Americas, and the global community are shown in Fig. 1. According to the Republic of Rwanda Ministry of Health, Rwanda provides its inhabitants a total of 45 hospitals (including 2 military/police hospitals and 4 referral hospitals) with 16,834 inpatient hospital beds, 428 health centers, 18 dispensaries, 34 health posts, and more than 428 health centers [10]. A district hospital is defined by the Ministry as an institution that includes all of the following components: "inpatient and outpatient services, surgery, laboratory, gynecology and obstetrics, and radiology" [10]. The level at which these services must be provided is not further defined.

Rwanda has taken some steps to evaluate availability and to coordinate provision of services at the district hospital level. In 2008, the Clinton Foundation supported the Ministry of Health in applying a costing and planning tool to all district hospitals in Rwanda, allowing hospital administrators to better understand and manage the costs associated with running a district hospital [11]. The Ministry of Health uses "performance-based financing" (PBF) and a "district health system strengthening tool" via the Internet to collect

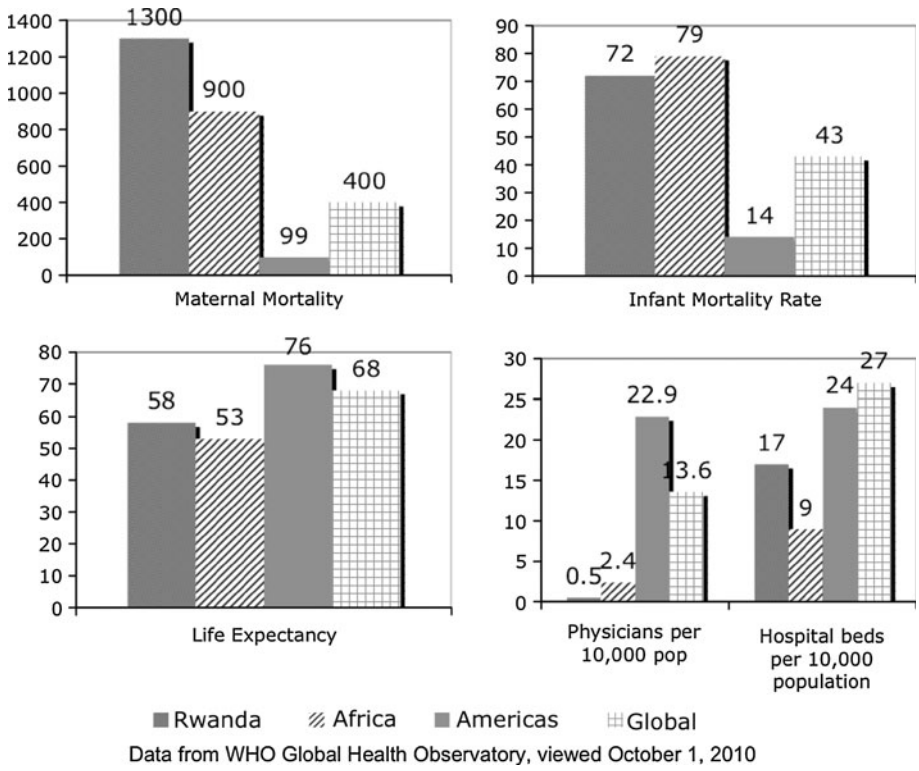

Fig. 1 Comparative health indicators

a select number of self-reported performance indicators from each of the district hospitals [11]. A summary of these databases shows that a total of 43,597 surgical interventions were performed during 2008 with more than half of all surgeries being "urgent" interventions. The most common operations reported by the district hospitals to the Ministry were cesarean sections (35.0%) followed by hernia repairs (2.9%) and curettage (2.5%) [11].

Methodology

A comprehensive survey tool was developed to assess physical infrastructure of operative facilities, education and training for surgical and anesthesia providers, and equipment and medications at district level hospitals in sub-Saharan Africa. This article focuses on the Rwandan results of this survey. Rwandan health indicators and national health system statistics found in recent literature provided an overview of the state of health resources in the country. The Ministry provided access to select indicators from their PBF system as a baseline measurement. District hospitals in Rwanda were randomly selected using convenience sampling such that hospitals were chosen by their geographic proximity to national roadways. Paved roads in Rwanda are limited. Therefore, hospitals were not chosen based on their proximity to the main roads but, rather, to reflect a variety of proximities to the main roads, both paved and unpaved. The goal of sampling was to attain at least two district or provincial (regional)-level hospitals per province, with at least one district hospital per province.

The survey examined eight areas of surgical and anesthesia care in detail: access and availability, access to human resources, infrastructure, outcomes, operating room information and procedures, equipment, nongovernmental organization delivery of surgical services, and pharmaceuticals. Results were obtained over a 2 week period by research at the Republic of Rwanda Ministry of Health and by visiting and directly surveying district and referral hospitals in each province of Rwanda. Referral hospitals were visited for comparative purposes, but the data collected at the referral facilities was not included in the reported results. No data specific to individual patients was collected at any of the facilities visited. All information was collected with the purpose of informing the international community in specific terms about surgical infrastructure, access to and availability of surgery at the district hospital level, access to and availability of anesthesia, surgical and other health care provider training programs, and the ability of the surgical system to collect and evaluate surgical outcomes.

Results

Access and availability of facilities

In Rwanda, heath care services are decentralized and provided at multiple levels, including community health

programs, health posts, health centers, district hospitals, and referral hospitals. This survey focused on care at the district hospital, with a total of 21 district hospitals surveyed, as shown in Fig. 2. In simplest terms, the district hospital is designed as a referral facility from the health center for the population assigned to each district hospital (designated by the Ministry as the "catchment area"), with subsequent referral to the referral hospital if necessary. The mean inpatient capacity found for the district hospitals was 8,525 patients per annum. This corresponds to a mean self-reported catchment population for each facility evaluated of approximately 282,769. The average district hospital has approximately 195 beds and three operating rooms. Patients have to travel a mean of 31 km (by foot, bike, or ambulance) to reach the appropriate district hospital (Table 1).

Access to human resources

In 2008, the Ministry of Health reported statistics of 384 Rwandan doctors and 187 full-time foreign doctors for a total of 571 physicians [11]. There were 5,885 nurses, 22 midwives, and 183 pharmacists during the same period. By 2009, there was a negligible increase, of 1.4%, in the number of physicians (579) along with a larger increase of 22.3% and 122.7% in the number of nurses (7,200) and midwives (49), respectively [10]. There was a 39.3% decrease, however, in the number of pharmacists. This is likely due to the slow emergence of training programs in Rwanda.

Rwanda currently has only one public university in the country, the National University of Rwanda (NUR). NUR hosts one medical school providing a 6 years bachelors degree in general medicine. Graduation requirements include successful completion of written and practical examinations. Upon matriculation, each physician must spend 2 years working at a district hospital as assigned by the Ministry of Health.

Postgraduate training programs in medicine are slowly gaining momentum. Most recently in 2005, NUR began offering a 4 years Master of Medicine (MMED) degree in pediatrics, internal medicine, surgery, gynecology-obstetrics, and anesthesia. Subsequent to an additional 4 years of training in one of the designated specialties and successful completion of a dissertation, written and oral examinations administered by NUR faculty must be passed. This is the only postgraduate training program in Rwanda for anesthesiologists and surgeons. The NUR program has been successful in establishing partnerships to ensure continuity of teaching. For example, in 2006 NUR established a collaborative effort for training in anesthesiology with the Canadian Anesthesiologists Society International Education Foundation (CASIEF) and the American Society of Anesthesiologists Global Humanitarian Outreach Program. The Ministry of Health selects candidates for these highly competitive specialty tracks, with preference given to those willing to serve the government in district hospitals rather than work in the private sector or for a nongovernmental organization (NGO).

There are only nine Rwandan physicians practicing anesthesia in the country, and they are all based in the three referral and teaching hospitals. There are no anesthesiologists available in the district hospitals, with the exception of two expatriates working in the East Province. There are

Fig. 2 District hospitals

District Hospital Key:

Kigali Provence
1. Kacyiru Police Hospital
2. Muhima Hospital
3. Kibagabaga Hospital

North Provence
14. Nemba Hospital
15. Ruhengeri Hospital

West Provence
16. Gisenyi Hospital
4. Murunda Hospital
5. Kibuye Hospital
6. Mugonera Hospital
7. Kibogora Hospital
8. Bushenge Hospital
9. Gihundwe Hospital

South Provence
17. Kigeme Hospital
18. Kabutare Hospital
19. Nyanzo Hospital
20. Kabagayi Hospital
21. Gitwe Hospital

East Provence
10. Rwamagana Hospital
11. Rwinkwavu Hospital
12. Kirehe Hospital
13. Kibungo Hospital

Referral Hospitals *(not shown on map)*
Centre Hopitalier Universitaire de Kigali
Centre Hopitalier Universitaire de Butare
King Faisal Hospital (Kigali)
Kanombe Military Hospital

Table 1 Surveyed district hospital access and availability

Province	Total	Kigali province	North province	West province	South province	East province
Population reported by the ministry of local govt. [12]	11,370,425	965,398 (2009)	1,650,704 (2009)	2,008,319 (year unknown)	2,266,124 (2007)	2,141,174 (2009)
No. of district hospitals	40	3	6	12	10	9
District hospital inpatient capacity (mean)	7713	11,485	10,227	6576	9695	6198
Catchment population per district hospital (mean)	282,769	289,766	433,877	149,167	364,545	262,373
Distance traveled to reach hospital (km) (mean)	27	52	28	25	28	28
No. of hospital beds per district hospital (mean)	195	141	291	166	233	168
No. of operating rooms per district hospital (mean)	3	3	4	2	3	2

17 Rwandan surgeons and seven expatriate surgeons who work in the referral hospitals. There are no trained surgeons based at the district hospitals, leaving surgical capacity at the district hospitals severely compromised. Consequently, only routine and emergency general and obstetric surgery is performed at most district hospitals, almost exclusively by general practitioners. More complex procedures are either scheduled for a visiting surgeon or, in the case of severe trauma, transferred immediately to one of the referral hospitals.

Training of allied health professionals in Rwanda is a relatively new and evolving discipline. The NUR Faculty of Medicine provides the only pharmacy-training program in the country with a bachelor degree in pharmacy. As of 2010, the curriculum is being revised to offer the 4 year bachelor degree in pharmacy with an opportunity to earn a master's degree after a fifth year. Rwanda does not have a pharmacy-technician training program. There is a Rwandan Association of Pharmacists, and the legal process is engaged to create a Board of Pharmacy or National Pharmaceutical Council. The total number of pharmacists currently in the country is slightly fewer than 200, with only a handful engaging in clinical work.

There are nine public nursing programs and nine public midwife programs in Rwanda. In 2007, Rwanda revised its nursing education programs and began training A-1 level nurses in a new 3 year, competence-based program that would provide graduates with a higher national diploma as a registered nurse or midwife. Prior to this program, nurses were classified as A-1 (3 years of training after secondary school) or A-2 (secondary school only: equivalent to a "nursing high school"). The A-1 diploma is not equivalent to a bachelor degree, but credit earned may be applied toward a bachelor degree.

In January 1997, the Ministry of Health in collaboration with the Ministry of Education created Kigali Heath Institute (KHI) in an attempt to solve the problem of inadequate health personnel following the tragic events of 1994. KHI is the only graduate school that offers a 3 year anesthesia technician A-1 level diploma. KHI students must first have completed A-2 level nursing education followed by a year of acquiring practical skills in "anesthetic practice" at referral and district hospitals. In September 2009, KHI enrolled 13 students in its first bachelor degree program in anesthesia; it consisted of 4 years of postsecondary school training. There is currently no master's level nurse anesthesia technician training program. Some A-1 certified nurses practice anesthesia at the district hospitals without specialty training in anesthesia. At this time, nurse practitioners are not being trained as surgeons.

In Rwanda, practicing physicians and nurses are required to be licensed. The Medical Council administers physician licensing and the Nursing Council administers nurse licensing. Currently, there is no council that provides pharmacy licensing, although practicing pharmacists must have completed a bachelor degree in pharmacy. There are currently no continuing medical education (CME) requirements for these professions and no recertification requirements. Health care societies, such as the Rwandan Society of Surgeons, Rwandan Society of Pharmacists, and Rwandan Society of Anesthesiology (presently inactive), are in their infancy. Although there are no "uncertified" health care workers[1] in Rwanda, nurses uncredentialed in anesthesia, midwifery, or pharmacy often work as anesthesia technicians, midwives, or pharmacists. For purposes of this survey, these nurses are qualified as "uncredentialed/".

The mean total number of physicians at a district hospital is 11. Almost all are general practitioners, with no surgeons or anesthesiologists available. The only surgical specialists available are those practicing obstetrics and gynecology, and they are scarce at best. There is a mean of three anesthesia technicians available per hospital with occasionally one uncertified nurse assisting in anesthesia. Additionally, there are three or four midwives at each

[1] Many personnel, mostly nurses, function in a capacity for which they have been trained on the job, but they have neither a degree nor a certificate of schooling in such capacity. For purposes of this survey, we have classified these personnel as "uncredentialed" in the specific capacity of their primary function.

hospital with the assistance of a mean of three nurses uncertified as midwives assisting with deliveries. Pharmacists are only rarely available at any given district hospital (statistically, fewer than one per hospital). Most hospitals have a mean of three to four nurses working in pharmacy.

The access to human resources at surveyed district hospitals is outlined in Table 2.

Infrastructure and access to oxygen and equipment

As in most low-income countries, physical infrastructure is lacking in Rwanda. At first glance, a source of electricity was reported available at all district hospitals visited. The 2009 Rwanda District Health Strengthening Tool reported that more than 90% of facilities had at least one functional autoclave and anesthesia machine [10]. Yet, a closer look indicates conflict in evidence, especially with regard to the sufficiency of generators, autoclaves, and surgical and anesthesia equipment. For example, recurrent power outages in the surrounding areas lead to frequent use of a backup generator. Several hospitals expressed concerned that their generator is not sufficient to meet the needs of the hospital. In addition, the high cost of electricity in Rwanda (approximately three to four times that of the mean cost in the United States) leads to an inability to utilize the generator at necessary levels [6]. In contrast, access to clean water is not a common problem articulated by the management of the district hospitals. For those few hospitals with interruptions in running water, reservoirs are available to supplement their needs. Additionally, hospitals most often reported that sanitation is provided by a cooperative.

Another significant challenge Rwanda faces is access to and maintenance of sufficient surgical and anesthesia equipment. Oxygen is expensive and difficult to procure for many of the outlying district hospitals (Table 3). Currently, the only source for oxygen cylinders (compressed oxygen) is in Kigali, a several-hour drive on dirt roads from many of the district hospitals. Hospitals must resort to using oxygen concentrators with their anesthesia machines, a technologic problem with some of the newer anesthesia machines. All hospitals reported having access to an oxygen concentrator for situations where compressed oxygen (either cylinder or piped) is not available. Several hospitals have anesthesia equipment that is unused because of the inability to perform simple repairs on the equipment or lack of training on how to use the machines. Pulse oximeter and other monitors are scarce for the same reasons.

Access to essential medications

The Ministry of Health publishes a National List of Essential Medications utilized by most district hospitals. District hospitals that have a Drug and Therapeutics Committee (DTC) may create their own, population-specific formulary as a subset of the national list. Seven surveyed hospitals had developed their own formulary. Medication distribution is centralized through a national distribution center in Kigali with several regional distribution centers in each province. When shortages (called "stock-outs") of medications occur at the district hospital level, they are usually due to regional and national stock-outs. Routine shortages of essential medications were reported by 19 of the 21 district hospitals surveyed. The anesthesia essential medication list for the district hospitals is shown in Table 4. According to the Ministry of Health, diazepam injection was the fourth most common stock-out

Table 2 Access to human resources at surveyed district hospitals

Human resources	Kigali province	North province	West province	South province	East province
Credentialed					
Physicians	15	14	8	10	9
Surg, Anesth, OB (MD)[a]	3	2	2	1	1
Nurses	103	100	59	74	73
Anesthesia technician	9	3	2	4	3
Pharmacist	2	2	1	1	1
Midwives	11	2	2	4	3
Noncredentialed					
Physicians	0	0	0	0	0
Surg, Anesth, OB (MD)	0	0	0	0	0
Nurses	0	0	0	0	0
Anesthesia tech	0	4	3	4	2
Pharmacy tech	4	9	5	6	5
Midwives	0	0	10	13	11

Surg Surgeons, *Anesth* anesthesiologists, *OB* obstetricians, *tech* technician

[a] No anesthesiologists at the district hospitals, only obstetrician-gynecologists and occasionally a visiting surgeon

Table 3 Infrastructure: equipment availability at surveyed district hospitals

Equipment	Kigali province	North province	West province	South province	East province
Oxygen in each OR	3 (100%)	3 (100%)	5 (83%)	3 (60%)	4 (100%)
Pulse oximeter in each OR	3 (100%)	2 (67%)	3 (50%)	0 (0)	4 (100%)
Pulse oximeter postop	2 (67%)	2 (67%)	2 (33%)	1 (20%)	1 (25%)

Results are the number of hospitals responding "yes"

OR Operating room, *postop* postoperatively

drug at the district hospitals in 2008. Antibiotics and pain medications are also included on the National List of Essential Medications.

Surgical volume

Despite the lack of surgical and anesthesia resources and providers, district hospitals perform a high volume of surgery. The hospitals surveyed reported an approximate total of 45,759 surgical cases per year. They also reported 18,488 emergency surgeries (including emergency cesarean sections), 28,137 general surgical cases, 526 pediatric cases (including circumcisions), and 19,297 obstetric and gynecologic operations. For the mean totals per hospital, there were 2,052 annual surgical cases, 1,197 emergency procedures, 1,189 general operations, 100 pediatric cases, and 878 obstetric-gynecologic cases (Table 5). It is interesting to note that hospitals reported a cesarean section rate of approximately 50%, with most being done on an emergency basis.

Outcomes tracking

All hospitals track overall operating room (OR) deaths as per a mandate from the Ministry of Health. Moreover, several hospitals have instituted a formal Morbidity and Mortality Committee (MMC) to discuss deaths, complications, and process improvements. For those hospitals without a formal MMC, the medical staff conducts an informal discussion during morning rounds or at least once a week. However, none of the hospitals was able to report a more sophisticated way to measure outcomes beyond OR death rates. Hospital administrators stated that complications, including surgical infections, were tracked on an individual patient basis but not as part of an overall report for the hospitals.

Another step toward outcomes tracking was the development of Drug and Therapeutic Committees (DTCs). Hospitals that reported having a custom formulary had also created a DTC consisting of several physicians, at least one pharmacist, and several department leads. Seven hospitals reported having a custom formulary and DTC or were in the process of starting a DTC. However, no hospital reported the ability to track adverse drug reactions or antibiotic resistance on a hospital-wide basis.

Although district hospitals do not have the capacity to monitor outcomes, they are responsible for reporting death rates to the Ministry of Health under the PBF system. The hospitals surveyed reported a total of 94 deaths in the operating room and due to surgery, nine deaths due to anesthesia but occurring immediately after the operation, 41 deaths due to surgery but occurring immediately after the operation, and seven deaths due to surgery but occurring during the first 24 h after surgery (Table 6). All hospitals reported that they investigate the cause of death. The most common causes of death reported were hemorrhage, anesthesia complications (including respiratory depression and high spinal), and death due to advanced disease and delayed treatment.

Tracking deaths was difficult for several reasons. Intraoperative deaths were tracked in the surgical case logs, with little differentiation as to a specific cause of death. There was poor and inconsistent postoperative tracking of deaths once patients went onto the wards; and therefore deaths on the ward were not consistently tracked back to surgery. The cause of death was usually not specified in the logs and was generally achieved with a "best guess" approach rather than a formal autopsy. Although some institutions monitored the surgical and anesthesia deaths, it was often difficult to determine the exact cause of death in this informal setting. Additionally, the immediate postoperative period varied by hospital, depending on both

Table 4 Essential medications at the surveyed district hospitals: anesthesia

Halothane
Ketamine
Bupivacaine
Nitrous oxide
Thiopental
Lidocaine (with and without epinephrine)
Atropine
Diazepam
Morphine
Neostigmine
Pancuronium
Succinylcholine
Vecuronium

Table 5 Surgical volume: surveyed district hospital OR procedures per annum

Parameter	Kigali province[a]	North province	West province	South province	East province
OR cases	817	3366	1412	3149	1275
Emergency surgical cases	692	1546	809	3255	819
General surgical cases	110	2438	633	2250	432
Pediatric surgical cases	95	90	62	235	34
Ob-Gyn surgical cases	1100	951	554	1099	866
Total cases per operating room	454	918	605	1211	728
General surgeries per operating room	41	685	271	866	247
Cases per anesthesia professional	306	918	605	1211	728

Results are the average number of each parameter per hospital

Ob-Gyn Obstetrics-gynecology

[a] Most of the referral hospitals are located in Kigali Province and are excluded from this study

Table 6 Outcomes: surveyed district hospital mean total reported deaths

Outcome	Kigali province	North province	West province	South province	East province
Deaths due to surgery while in OR[a]	5 (0.6%)	29 (0.9%)	11 (0.8%)	42 (1.3%)	7 (0.5%)
Deaths due to anesthesia immediately postop	Unk	1	6	Unk	2
Deaths due to surgery immediately postop	Unk	32	7	1	1
Deaths due to anesthesia within 24 h postop	Unk	Unk	Unk	Unk	Unk
Deaths due to surgery within 24 h postop	Unk	1	4	Unk	Unk
No. of OR cases (mean)	817	3366	1412	3149	1275

Unk Unknown

[a] Numbers in parentheses are the percent of total OR cases

physical and human resources. Unless there was a clear case of spinal shock, it was difficult to capture data on whether a patient died because of the anesthetic agent, hemorrhage, advanced sepsis, or surgical error. This is highlighted by the fact that often there was poor intraoperative monitoring, with some hospitals not having the basic essentials for such determinations, such as pulse oximetry. Most of the intraoperative deaths were due to hemorrhage because of minimal blood banking resources. In other words, these intraoperative deaths may be largely preventable if there are better resources on hand.

International organizations and NGOs

Many international organizations and NGOs had a presence at the district hospitals. Based on the significant involvement of NGOs in many areas of care, including surgery and anesthesia, we were unable to quantify the presence of NGOs at the district hospital level. Additionally, it was unclear how the NGOs selected (or were invited by the Ministry) to participate with a particular district hospital. Five of the hospitals surveyed were mission hospitals categorized as such by partial funding or involvement by a religious denomination with cooperation of the Ministry.

Discussion

With a paucity of surgical providers and even fewer anesthesia resources in Rwanda, the global community must commit to building a relevant safe surgical infrastructure in this country. Rwanda's biggest challenge is one of human resources—both training and retraining of the health care providers [13–15]. Given the young nature of the Rwandan training programs, this is an evolving problem. Retaining physicians who would otherwise seek postgraduate training outside Rwanda is a challenge given the huge caseloads physicians in Rwanda must manage. There is less than one anesthesiologist and surgeon available per operating room, yet there are anywhere from 306 to 1,211 annual cases per operating room throughout the country.

Provision of safe surgery and anesthesia in district hospitals requires high-quality trained personnel, safe equipment, and consistent access to blood and oxygen to meet safety standards. With almost 11 million people in Rwanda, much of the burden of anesthesia delivery is placed on technicians, unsupervised by physicians, who have limited expertise in acute and complex medical situations. Added to the complexity is the inability to have

consistent access to resources, such as monitoring equipment, blood, oxygen, and pharmaceuticals. The end result is a failure to provide safely and consistently most emergency and essential surgical and anesthesia services at a district hospital level. At this point of care, some services such as operative trauma management are neglected entirely.

All surgical volumes and mortality numbers were recorded from various sources within the hospital. In most cases, surgical volumes had to be estimated from surgical records and log books. Additionally, mortality numbers are reported to the Ministry of Health as part of the funding process. There is legitimate concern by hospital administrators that mortality information could be misused and therefore underreported. Moreover, given the lack of resources to care for critically ill surgical patients, it is highly likely that many surgical patients are transferred to a referral facility before complications occur. All of these factors lead to underreporting of the true surgical burden at the district hospital level. Nonetheless, the surgical volume and mortality numbers collected indicate high surgical demand at the district hospital level.

Although convenience sampling has limitations, accessibility to the hospitals from the roads in each province was the main reason for having chosen a convenience sample. Although this survey was not a random sample whereby each member of the population had an equal probability of being selected, most of the sites we visited see patients who are fairly representative of the whole population. For example, the patients in all districts outside of the capital, Kigali, were of comparable socioeconomic status and health status to those who live in the most remote areas. Here, the hospital sampling does cover a significant portion of the population. The authors recognize the limitations of convenience sampling; but given that each province is represented and that more than 50% of the hospitals were surveyed, these data are valuable to the international community when considering the global burden of surgical disease and limited access to surgical care in low-income countries. Convenience samples can provide useful information regarding preliminary trends for pilot studies such as this one.

In terms of infrastructure, most hospitals reported lack of continuous access to electricity, water, oxygen, and monitoring equipment for their operating rooms. In fact, 100% of hospitals report a lack of supplies that are important and in some cases critical for providing surgery and anesthesia. Hospitals that had sufficient equipment reported an inability to use it consistently owing to either lack of training on how to use the equipment safely or how to maintain it. Coordination and evaluation of donated equipment and necessary educational training and biomed support by NGOs does exist and is in the preliminary stages of development. Extensive planning and coordination between the Rwandan government and NGOs is needed to make surgical and anesthesia services safe and effective across the country.

Financial resources are necessary to support Rwanda's continued development of a new and improved health care system. A major commitment from the Ministry, the National University, the WHO, and the international medical community is necessary to facilitate district hospital growth. Rwanda needs to ensure consistent provision of basic surgical resources, including, without limitation, reliable anesthesia equipment for each operating room, dedicated post-surgery recovery areas and surgical intensive care units with dedicated personnel and monitoring equipment. Better coordination is needed to ensure that the consumables and essential medications necessary are provided in a reliable to facilitate the everyday work of the general practitioners, surgeons, and anesthesia providers working with surgical patients. In addition to the dependable provision of basic anesthesia medications, there is a need to extend the choice and availability of these drugs. Additionally, collaborative partnerships should be examined to facilitate delivery, maintenance of, and teaching around essential equipment and pharmaceuticals in the most cost-effective manner.

The first step in improving surgical services in low-income countries is knowing what exists. The Ministry or another governmental agency in Rwanda needs to create an inventory of current functional resources so they can coordinate efforts to fulfill deficiencies. Also, the Ministry must acknowledge acceptance of international guidelines for emergency and essential surgery. Specific health indicators need to be put in place to measure change at the district hospital level *as it occurs* rather than stifle accurate reporting through the use of PBF. There are many opportunities to improve access to and the safety of surgery and anesthesia in Rwanda. These opportunities are typical of low-income countries and, if documented, may be globally advocated for by Rwanda and other international groups.

Serious deficiencies in human resources are expected given the history and geography of Rwanda. Rwanda has already recognized that they must train locally for sustainability. There is a critical need to improve the number of trained surgeons, anesthesiologists, and other professionals who are competent in the emergency and essential surgical cases that most frequently confronted at the district hospital level. There is also a huge need to increase educational and research opportunities for these professionals starting in medical school. The ministers of health and finance must recognize the importance of specialty training and create both financial and educational incentives for specialty training. Addressing and recognizing financially the heavy workload of the physicians at the district

hospitals is one step toward addressing the biggest opportunity: creation and retention of human resources. In addition, Rwanda should continue to explore models for enhancing their training programs for both physician providers and nonphysician providers. It includes continuing to develop physician specialty programs and cross-training nonspecialist physicians. Nonphysician providers are invaluable in areas of limited resources. Training of nonphysician providers has already taken place with regard to the nurse-anesthetist training program. Future models may also include surgical task shifting with adequate training and supervision [16].

Conclusions

Most low-income countries lack emergency and essential surgical services and a safe anesthesia infrastructure [17]. Rwanda is no exception, although some efforts in improving its surgical and anesthesia infrastructure are evident. Previous surveys of district hospitals in low-income countries serve to inform the international community of the ongoing surgical and anesthesia crisis and the need to strengthen entire health systems in developing countries [17, 18]. In addition, the WHO and other groups have offered international recommendations that district level hospitals provide emergency and some essential surgery and that such hospitals follow guidelines for the provision of safe surgery and anesthesia [19–21]. Survey data are necessary to evaluate the baseline resources necessary for compliance with these guidelines. Until now, these data have been lacking in Rwanda. This survey of Rwanda's health care system provides strong evidence to support continued development of emergency and essential surgical care at district hospitals to improve health care and to comply with the WHO recommendations. It has identified serious deficiencies in both financial and human resources—areas where the international community can play a role.

Surgical interventions are essential to improving the health of the population in Rwanda. The leading global causes of death include cardiovascular disease, trauma, and cancer, each of which has appropriate surgical interventions [22]. Maternal mortality, a key indicator of the Millennium Development Goals, can also be reduced by the provision of appropriate and timely surgical interventions [23, 24]. The challenges for providing emergency and essential surgical services are many, but the benefits including overall improvement of the health care system and decreasing premature disability and death, far outweigh the challenges.

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