



Equipment for essential surgical care in 9 countries across Africa: availability, barriers and need for novel design

R. M. Oosting¹ · L. S. G. L. Wauben^{1,2} · R. S. Groen³ · J. Dankelman¹

Received: 18 June 2018 / Accepted: 2 November 2018 / Published online: 9 November 2018
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Abstract

Shortages of medical equipment in low-and-middle income countries (LMICs) have been found by several previous studies that assessed surgical capacity. To increase surgical capacity, there is a need to identify the availability of specific types of surgical equipment on a local, regional and national level. A survey was conducted among surgeons attending the annual meeting of the College Of Surgeons of East, Central and Southern Africa (COSECSA) in December 2016. General information of the facilities, availability of surgical equipment, reasons for limited availability, daily usage of equipment and equipment that could benefit from redesign were assessed. Forty-two respondents participated in this study, representing 33 individual healthcare facilities (14 public referrals, 9 public district and 10 private (for-profit and non-profit)). The respondents worked in 9 countries in East, Central, Western and Southern Africa. A deficiency in availability of basic surgical equipment was found, especially in public district hospitals. Electrosurgical units, endoscopes, defibrillators, infusions pumps and electrocardiogram monitors were of limited availability. Reasons indicated for this limited availability were: no need, too costly, no training, no disposables and no repair. Lack of maintenance and old/overused equipment were identified as major reasons for failure of equipment. Equipment that could benefit from redesign were for example: electrosurgical units, laparoscopic equipment and theatre lights. Availability of surgical equipment should be increased, especially in public district hospitals. Novel context appropriate redesign that is adapted to fit the context in LMICs could decrease the barriers to availability and to failure of surgical equipment.

Keywords Surgery · Medical equipment · Low-and-middle income countries · Maintenance

1 Introduction

Global public health initiatives have neglected the necessity for provision of surgery for decades. However, recently surgery is increasingly recognized as an important component of public health [1, 2]. There is a significant disparity between surgical procedures performed in high-income countries (HICs) and low-and-middle income countries (LMICs), only 3.5% of the surgeries performed in the world are received by

the poorest one third of the world's population [2]. The common notion that surgery is too complex and too expensive to implement in public health interventions is changing. Surgery, is complex and relies on availability of equipment, however patients can recover from their disease and are less likely to be under continuous surveillance for their disease in contrast to an infectious disease such as HIV [3].

Surgical care across Africa is provided by the private and the public healthcare sector, where the public healthcare sector is roughly subdivided in health centers, district and referral hospitals. Based on the guidelines of the World Health Organization (WHO) on essential and emergency surgical care, public district hospitals in LMICs should have adequately equipped major and minor operating theatres (OTs) [4]. These public district hospitals should be able to provide short-term treatment of 95–99% of all life-threatening conditions. Public referral hospitals should be equipped with basic intensive care facilities and should be able to provide all treatment that is offered in public district hospitals with the addition of thoracic trauma care, complex eye surgeries and major

✉ R. M. Oosting
r.m.oosting@tudelft.nl

¹ Department Biomechanical Engineering, Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands

² Research Centre Innovations in Care, Rotterdam University of Applied Sciences, Rochussenstraat 198, 3015 EK Rotterdam, The Netherlands

³ Department Gynecology and Obstetrics, Johns Hopkins University, 601 N Caroline St, Baltimore, MD 21231, USA

gynecological surgeries [4]. To achieve the targets of the WHO, increased workforce capacity, but equally important, increased availability of surgical equipment is required. This requires strategic investments from stakeholders, such as local governments, biomedical engineers, biomedical equipment technicians (BMETs) and medical device companies [5].

The role of biomedical engineers, BMETs and medical device companies in increasing availability of surgical equipment is already widely acknowledged [5–7]. Barriers unique to usage of medical equipment in LMICs were identified before [8], and the WHO ‘Priority Medical Devices Project’ identified a mismatch between the design of medical devices and the context in which medical equipment is used in LMICs [6].

Inventories of surgical capacity across sub-Saharan Africa have been made by different authors based on different surgical capacity tools: shortages of equipment were found in Nigeria [9], Cameroon [10], Sierra Leone [11], Somalia [12], Ethiopia [13], and Malawi [14]. However, there is a need to identify the mismatch of specific types of surgical equipment on a local, regional and national level to plan future strategic investments. Therefore, the aim of this study is trifold:

- 1) to highlight the current availability of surgical equipment in public (district and referral) and private (for-profit and non-profit) hospitals across Africa,
- 2) to indicate the barriers surgeons experience on a daily basis in their efforts to assist in the population’s health needs, and
- 3) to identify equipment that could benefit from context appropriate design.

2 Method

Surgical equipment that is essential to be able to perform safe surgery on both district and referral level in public, mission and private hospitals was identified by reviewing the following two guidelines and two tools:

- a. the WHO guideline to infrastructure and supplies at various levels of healthcare facilities [4],
- b. the WHO guideline for generic essential emergency equipment [15],
- c. the WHO tool for situational analysis to assess emergency and essential surgical care [16], and
- d. the PIPES tool (Personnel, Infrastructure, Procedures, Equipment and Supplies tool) to assess surgical capacity [17].

Guidelines a and b were developed by the WHO within their global initiative on emergency and essential surgical care. Tools c and d are the most frequently used tools to assess surgical capacity globally. It was believed that these

guidelines and tools form a comprehensive basis for equipment required for essential safe surgery on both district and referral level in public, mission and private hospitals. Essential surgical equipment presented in these guidelines and tools that require batteries or electricity were included in this study.

Based on these four guidelines and tools a list of 13 equipment items essential for surgical care was established consisting of: oxygen concentrator, anesthesia machine, pulse oximeter, suction pump, blood pressure measurement equipment, sterilizer, theatre light, electrosurgical unit (ESU), endoscope, electrocardiogram (ECG) monitor, infusion pump, defibrillator and laryngoscope.

A survey was developed to assess the availability of equipment required for essential surgical care across Africa. The survey consisted of four parts:

1. General information of each hospital (name, country, number of beds, number of OTs, availability of surgeons and biomedical equipment technicians (BMETs).
2. Availability of surgical equipment and reasons for limited availability (no need, too costly, no training, lack of spare parts, need for repair, lack of disposables or lack of energy or other). Participants were asked to indicate only the main reason for limited availability of equipment in their hospital.
3. Daily use of surgical equipment and the implications of malfunctioning equipment to patients (e.g., problems with equipment, reasons for failure of equipment, percentage of times surgeries are delayed or cancelled).
4. Maintenance, barriers during usage, and possible solutions and options for redesign of surgical equipment (e.g., what sort of maintenance is available, which equipment should be redesigned for more successful implementation).

The survey was conducted among surgeons working in African based hospitals who attended the annual meeting of the College Of Surgeons of East, Central and Southern Africa (COSECSA) in December 2016.

Hospitals were stratified into self-reported levels of care either public district or public referral or assigned as being private (for-profit or non-profit). No distinction between for-profit and non-profit was made since both categories of private hospitals do not fall under responsibility of the Ministry of Health (MoH) in terms of budget allocations, in contrast to public hospitals.

3 Results

A total of 42 surgeons attending the conference participated. They represented 33 individual hospitals, 10 private hospitals (for-profit and non-profit), 14 public referral hospitals, and 9 public district hospitals (Table 1). Respondents were working

Table 1 General information of the respondents

Hospitals category	Private/NGO/Mission (for-profit & non-profit) (<i>n</i> = 10)	Public (<i>n</i> = 23)	
	Private (<i>n</i> = 10)	Public referral (<i>n</i> = 14)	Public district (<i>n</i> = 9)
Number of respondents	16	16	10
Number of hospital beds (for surgical and medical cases)	1926 (196, 64–380)*	10,945 (622, 100–2000)* (<i>n</i> = 10)	2470 (200, 50–500)*
Number of operating theatres	43 (4, 2–8)*	139 (8, 4–18)* (<i>n</i> = 12)	27 (2, 1–7)*
Number of personnel performing surgery	148 (14, 5–30)*	319 (28, 3–50)* (<i>n</i> = 11)	98 (10, 4–30)*
Hospitals with biomedical equipment technicians	8	12	7

*(total (median, range))

in 9 countries in East, Central, Western and Southern Africa: Kenya [18], Zambia [2], Ethiopia [2], Zimbabwe [1], Uganda [1], Malawi [2], Congo [2], Mozambique [3] and Nigeria [1], and 9 surgeons did not specify the country they were working in.

4 Availability of surgical equipment

Overall, the availability of surgical equipment was less in public district than in private and public referral hospitals (Fig. 1). On average, overall equipment availability was indicated by 87.5% of the respondents from private hospitals, by 70% of the respondents from public district and 81% of the respondents from public referral hospitals. Blood pressure measurement equipment and laryngoscopes were available for all respondents. All respondents working in private and public referral hospitals had access to anesthesia machines, for public district hospitals this was 90%. Endoscopes, defibrillators, infusion pumps and oxygen concentrators were of limited availability in public district hospitals.

4.1 Main reasons for limited availability of surgical equipment

Respondents were asked to choose between categories (no need, too costly, no training, lack of spare parts, need for repair, lack of disposables or lack of water/electricity) and indicate the main reason why equipment was of limited availability within their facility. A total number of 86 reasons for limited availability were given by the 42 respondents. Figure 2 shows the reasons for limited availability of surgical equipment per hospital category. Too costly was indicated to be the largest reason for limited availability in all three hospital categories (ranging from 33% to 71%). The second most mentioned reason was lack of repair (21–22%). No training and no disposables were reasons for limited availability mentioned by respondents in public district and public referral hospitals (no training ranging from 26% to 17% and no disposables ranging

from 3% to 4%, respectively). Lack of water/electricity was mentioned by respondents from public district hospitals only (3%). Lack of spare parts was not reported as a reason for limited availability by any of the respondents.

4.2 Problems regarding equipment and availability of maintenance

Delay and cancellation of surgery due to malfunctioning equipment was self-reported to be lower in private hospitals (delay and cancellation $\leq 8\%$) than in public hospitals (district and referral $\geq 20\%$ delay and cancellation) (Table 2).

Sixty eight percent of respondents have access to maintenance facilities within their hospital and 36% of respondents have access to maintenance provided by service contracts. Ten percent of respondents indicated they have no access to maintenance facilities if equipment breaks. Eighty percent of respondents indicated that BMETs are working in their hospital with an average of 2.8 years of training.

All respondents indicated that they experience failure of surgical equipment. In total 53 reasons for equipment failure were self-reported. Lack of maintenance was reported the most as reason for failure (47%), followed by failure due to old or overused equipment (36%). Failure as a result of limited infrastructure facilities (mainly power outages) was reported by 11% of respondents. Finally, 5.5% of respondents reported that lack of finances caused failure of surgical equipment.

4.3 Barriers during usage and suggestion for redesign of surgical equipment

Thirty-nine respondents responded to the question if redesign is required for the context they work in. Twenty-five respondents (64%) agreed that redesign of surgical equipment could improve availability of surgical equipment in LMICs. Table 3 presents barriers 13

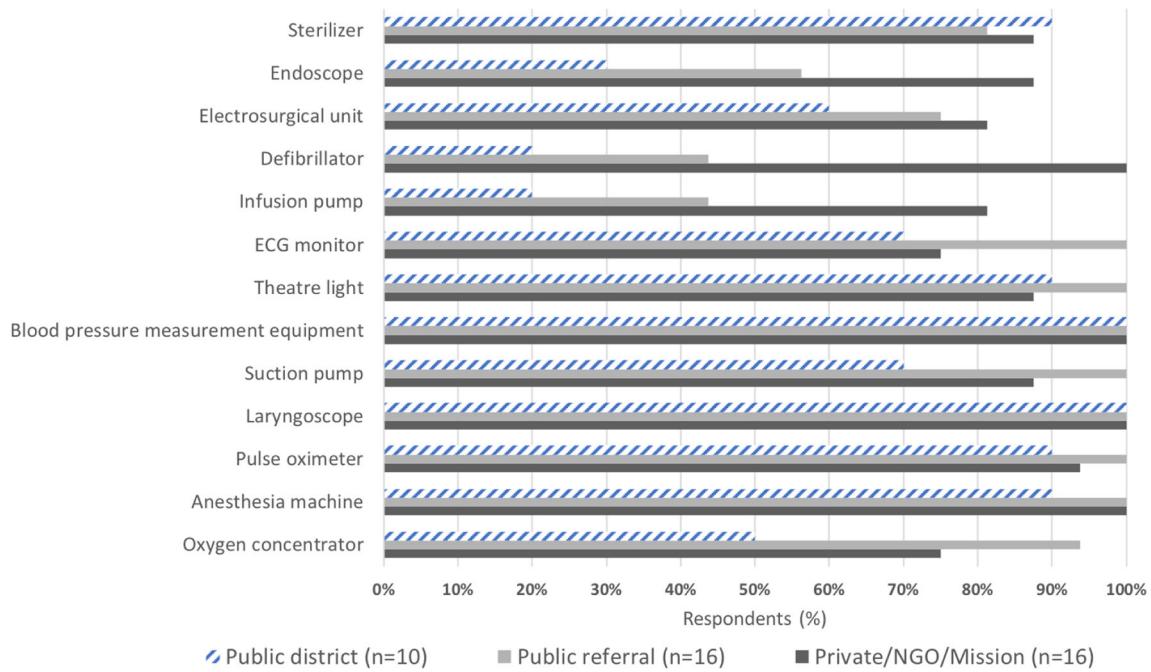


Fig. 1 Availability of surgical equipment (in percentages) indicated by the respondents (n = 42)

respondents encountered during usage and possible solutions and suggestions for redesign.

5 Discussion

Our results show important deficiencies in the availability of basic surgical equipment across Africa. Equipment, such as defibrillators, infusion pumps, endoscopes and oxygen concentrators had limited availability in public district hospitals.

As expected, the results of our survey (Fig. 1) showed that private and public referral hospitals had more surgical equipment available (88% and 81%, respectively) than public district hospitals (70%). Unfortunately, availability of surgical equipment was only described in literature for 84 public referral and private hospitals in Sierra Leone, Nigeria, Liberia, Ghana, Ivory Coast, Burkina Faso, Guinea, Niger, Senegal, Togo, and Uganda [9, 18, 19]. The results of this survey showed higher availability for endoscopes, ESUs, pulse oximeters and anesthesia machines than previously published

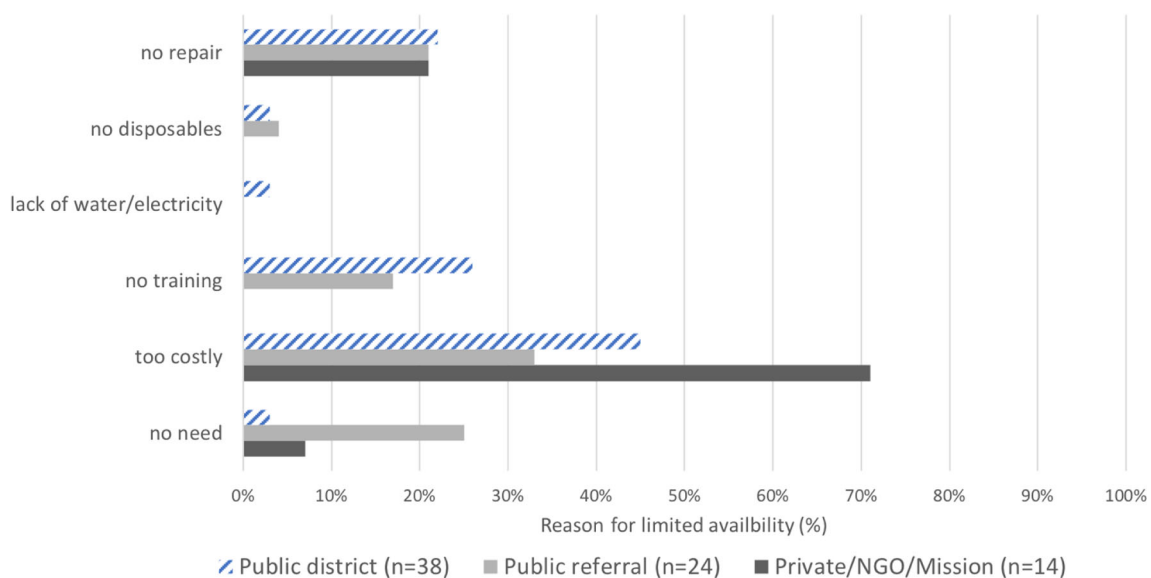


Fig. 2 Reasons for limited availability of surgical equipment (86 reasons) indicated by the 42 respondents

Table 2 Percentage of delayed and cancelled surgeries per hospital category due to malfunctioning equipment

	Private/NGO/Mission (<i>n</i> = 16)	Public district (<i>n</i> = 10)	Public referral (<i>n</i> = 16)
Delay surgery (%)	8% (1% - 50%)*	20% (5% - 70%)*	25% (1% - 80%)*
Cancel surgery (%)	2% (0% - 10%)*	20% (0% - 50%)*	20% (0% - 50%)*

*median (range)

data, especially for private hospitals. Our survey showed that in public district hospitals (*n* = 10), 30% had an endoscope, 60% had an ESU, 90% had an anesthesia machine. No published data was found on availability of surgical equipment in public district hospitals to compare our survey data to. This indicates a clear need to identify availability of surgical equipment in public district hospitals in future studies.

Respondents in all three hospital categories assigned high costs and no repair as major reasons for limited availability of equipment (Fig. 2). Additionally, all respondents indicated problems with failing surgical equipment in their hospital, mainly due to lack of maintenance and old and overused equipment. Lack of spare parts was not mentioned as a reason for limited availability by the respondents within this study, probably because surgeons might not be aware of the necessity of spare parts to maintain equipment. The majority of our respondents relied on maintenance within the healthcare facility. Maintenance in hospitals in LMICs relies heavily on the skills and knowledge of the BMETs, and the availability of tools and access to spare parts within the hospitals, in comparison to HICs where maintenance of equipment is often provided by the medical device company. Strategic investments in BMET training could have a significant impact in LMICs.

Additionally, a complete toolkit, maintenance budget and access to technical expertise (for example via the internet) are required [20]. For example, Bradley et al. (2015) estimated that the useful lifespan of oxygen concentrators in LMICs could reasonably exceed seven years when maintenance, with a low skill and knowledge level, and repairs (for less than 10\$) are in place [21].

The percentages of surgeries that were cancelled or delayed due to malfunctioning equipment was lower in private hospitals than in public hospitals, which might indicate that the quality of the equipment is higher and that the skills and knowledge of the BMETs is better in private hospitals. Future research is required to identify the differences in skills and availability of tools between BMETs in the different hospital categories (private, district or referral) and if they comply to the needs of the equipment required to perform essential surgical care. Additionally, more insight in the procurement process within the different hospital categories across Africa is required to design successful implementation strategies of surgical equipment.

One strategy to increase the availability of surgical equipment could be the design and implementation of equipment that is adapted to fit the context in LMICs. The context around

Table 3 Barriers encountered by 13 respondents during usage and possible solutions for redesign

Type of surgical equipment	Barriers for/during usage	Possible solution / Suggestions for redesign
Drills	Reuse of drills between surgery	Sterilize only parts that need to be sterile
Electrosurgical unit handhelds	Designed for single use Electrodes breakdown	Reusable electrodes
Electrosurgical unit Theatre lights	High costs	xx
Electrosurgical unit Theatre lights	Expensive spare parts Power fluctuations	Robust devices
Staples		
Laparoscopic equipment	Limited available	Acquisition of refurbished models
Monitoring device during anesthesia in rural settings	Lack of trained personnel Lack of manufactures High costs	Partner with private settings
Sterilizers	Limited available Power outages	Autonomous/ portable machines
Suction machine	Frequent break downs	Regular maintenance
Theatre tables	Cannot be altered in height	xx
Water filtration	Hard tap water that is used leaves saline, so machines that use tap water break down.	xx

XX not answered by the respondents

surgical equipment in LMICs differs from HICs, mainly in terms of financial resources and access to maintenance, spare parts and consumables [7]. The WHO issued a compendium of medical devices especially for LMICs to present an overview of devices that are likely to fit the context [22]. Examples of context appropriate designs are the anesthesia machines that have been brought to the market in LMICs by the companies such as Diamedica and Gradian health systems.

Our survey revealed that 64% of respondents agreed that there is a need for design that is adapted to fit the context in LMICs to increase availability of surgical equipment. Research has shown that equipment does not necessarily need to be simpler, but should be adapted to fit the context in LMICs [6–8]. Since, high costs (Fig. 2) and limited access to maintenance facilities (Fig. 2 and reasons why equipment fails found within this study) were identified in this study as reasons for limited availability and failure of equipment, redesign should take these aspects into consideration. Suggestions given for redesign of surgical equipment presented in Table 3 show that ESUs could benefit from redesign in terms of reducing costs and by providing electrodes for multiple use. Adjustments to enhance functioning of devices during power outages were suggested for ESUs, theatre lights and sterilizers.

Future (re)design should consider that equipment is operated in environments with high temperatures, altitudes, local voltage outlets and humidity [23]. Furthermore, manuals should be provided in the major local languages. By using generic parts that are easy to access in LMICs, BMETs can easily replace these parts. This would reduce the need for service contracts with medical device companies that are often based outside of LMICs.

This study has some limitations. Firstly, the survey data included 42 respondents representing 33 individual hospitals. This means that some hospitals were represented by multiple respondents. It is expected that this has influenced the results of the availability of equipment, especially in private hospitals since 10 individual hospitals were represented by 16 respondents. However, no differences in availability of equipment between overlapping respondents were found. Reasons for limited availability did differ between respondents that represented the same hospital. Secondly, it can be assumed that hospitals represented in this study had certain financial resources to let their employees attend the annual meeting of COSECSA in Kenya, which means that the hospitals represented in this study are not representative for all hospitals across Africa. This was a survey of surgical academic forum attendees, so the data of rural hospitals was under-represented. Thirdly, all respondents were surgeons who might not be aware of the reason why equipment cannot be repaired. Therefore, this study might underestimate the need for spare parts.

The equipment that was found to be limited available, as well as reasons for limited availability and failure indicated in this study, show that there is a large need for future research

regarding surgical equipment in LMICs. During our future research, different hospital categories in LMICs will be visited to include facilities that might not be covered in this study. Additionally, BMETs views on reasons to limited availability of surgical equipment and suggestions for (re)design will be researched too. Despite these limitations the gap between hospitals' needs to provide safe surgery and hospitals resources is highlighted by this study. The availability of surgical equipment is vital for hospitals' capacity to provide safe surgery but also vital to work on retaining of surgical and anesthesia providers by increasing their work satisfaction since their quality of work relies on this equipment.

6 Conclusion

This study revealed deficiencies in the availability of basic surgical equipment in nine countries across Africa, mainly in public district hospitals. Redesign that is adapted to fit the context in LMICs could decrease the reasons for limited availability and failure of equipment identified within this study. Among other equipment the ESU, laparoscopic equipment, and theatre lights are identified as equipment eligible for redesign to increase availability in LMICs. To increase availability of surgical equipment and increase surgical capacity in LMICs collaboration between surgeons, surgical training programs, biomedical engineers, BMETs and companies is highly recommended.

Funding This research was funded by the Delft Global Initiative of the Delft University of Technology, Delft, The Netherlands (P70357).

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of interest Author R. M. Oosting declares that she has no conflict of interest. Author L. S. G. L. Wauben declares that she has no conflict of interest. Author R. S. Groen declares that she has no conflict of interest. Author J. Dankelman declares she has no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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