Anesthesia capacity of district level hospitals in Malawi, Tanzania and Zambia - a mixed-methods study.

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Abstract

Background: District level hospitals are the main providers of surgical services for rural populations in Sub-Saharan Africa (SSA). Skilled teams are essential for surgical care and gaps in anesthesia impact negatively on surgical capacity and outcomes. This study, from a baseline of a project scaling-up access to safe surgical and anesthesia care in Malawi, Tanzania and Zambia, illustrates the deficit of anesthesia care in district level hospitals (DLHs).

Methods: We undertook an in-depth investigation of anesthesia capacity in 76 DLHs across the three countries, July-November 2017, using a mixed-methods approach. The quantitative component assessed district level anesthesia capacity using a standardized scoring system based on an adapted and extended Personnel, Infrastructure, Procedures, Equipment and Supplies (PIPES) Index. The qualitative component involved semistructured interviews with providers from 33 DLHs, exploring how weaknesses in anesthesia impacted district surgical team practices and quality, volume and scope of service provision.

Results: Anesthesia care at district level in these countries is provided only by non-physician anesthetists, some of whom have no formal training. Ketamine anesthesia is widely used in all hospitals, compensating for shortages of other forms of anesthesia. Pediatric-size supplies/equipment were frequently missing. Anesthesia PIPES index scores in Malawi (M=8.0), Zambia (M=8.3) and Tanzania (M=8.4) were similar (p=0.59), but an analysis of individual PIPES components revealed important cross-country differences. Irregular availability of reliable equipment and supply is a particular priority in Malawi, where only 29% of facilities have uninterrupted access to electricity and 23% constant access to water, among other challenges. Zambia is the most affected by staffing shortages, with 30% of surveyed hospitals lacking an anesthesia provider. The challenge that stood out in Tanzania

was non-availability of functioning anesthesia machines among frequent shortages of staff and other equipment.

Conclusion: Tanzania, Malawi and Zambia are falling far short of ensuring universal access to safe and affordable surgical and anesthesia care for district and rural populations. Mixed methods situation analyses, undertaken in collaboration with anesthesia specialists – measuring and understanding deficits in district hospital anesthetic staff, equipment and supplies – are needed to address the critical neglect of anesthesia, essential to providing surgical responses to the needs of rural populations in SSA.

Key points

- **Question:** Considering the lack of published country-specific empirical studies comparing anesthesia capacity across countries using standardized and validated methods, what is the current state of anesthesia care at district hospitals in Malawi, Zambia and Tanzania?
- **Findings:** None of the surveyed hospitals met international minimum safety standards for anesthesia and an in-depth investigation brought to light major cross-country differences in availability of essential anesthesia personnel, equipment and supplies.
- **Meaning:** Country-specific interventions are urgently needed to improve anesthesia care at district level, if the surgical needs of rural populations are to be addressed.

Glossary of Terms

CO: Clinical Officer

DLHs: District Hospital

LIMCs: Low and Middle Income Countries

NPAPs: Non Physician Anesthesia Providers

NPCs: non-physician clinicians

NSOAP: National Surgery Obstetric and Anesthesia Plan

OT: Operating Theatre

PIPES: Personnel, Infrastructure, Procedures, Equipment and Supplies

REC: Research Ethics Committees

SSA: Sub-Saharan Africa

SURG-Africa: Scaling up Safe Surgery for District and Rural Populations in Africa

Introduction

The last decade has seen growing efforts to ensure anesthesia and surgical care are prioritized within national health systems in low- and middle-income countries (LMICs) [1,2]. Despite increased global investments, 4.8 billion people still lack access to safe surgical and anesthetic care [3–5]. Sub-Saharan Africa (SSA), with its predominantly rural population, is most affected[1,3].

Government and faith-based district level hospitals (DLHs) are the main surgical service providers outside of main cities in SSA, yet most struggle to meet demand [1]. DLHs undertake obstetric surgery, but many perform relatively low numbers of major general surgery [6,7], with poor anesthesia capacity among the key obstacles [5,8].

The density of anesthesiologists in SSA is very low compared with developed countries[9] and those few are concentrated in urban areas[1], resulting in anesthesia care in rural settings being primarily provided by nurses and non-physician clinicians (NPCs)[10–12] known as Non Physician Anesthesia Providers (NPAPs) and referred as such herein. NPAPs have varying levels of education and training, and may or may not be credentialed or licensed [10,13,14]. NPAPs often practice without supervision or refresher training to maintain their skills [5]. Moreover, in the resource-limited settings where NPAPs operate, minimum standards for manpower, infrastructure and supplies necessary for safe anesthesia delivery are often not met [15].

Surveys are commonly used to measure these deficiencies, but normally without an in-depth investigation of their drivers and consequences. There is also a dearth of published country-specific empirical studies [16] and analyses comparing anesthesia capacity across countries using standardized and validated methods. This paper aims to close this gap by measuring and exploring shortages based on a mixed-methods study done in three SSA countries. The use of mixed-methods has been recommended as a way to overcome the limitations of surveys[17,18]. The quantitative component aims to provide a standardized and comparable assessment of

district level anesthesia capacity in the study countries, while the qualitative component explores how weaknesses in anesthesia affect routine practices of district surgical teams and quality of surgical care available to rural populations.

The study was undertaken as part of the Scaling up Safe Surgery for District and Rural Populations in Africa (SURG-Africa) project 2017-2020, conducted in Malawi, Tanzania and Zambia. SURG-Africa aims to improve surgical care delivery at DLHs. A situation analysis was conducted in 2017 to inform the intervention and national surgical, obstetric and anesthesia planning[19]. This study, designed by health systems researchers and national surgical leaders, was conducted to assess baseline surgical capacity in the participating countries in a way that allows for multiple time point measures, and the tools used reflect that (see Methods). A specific focus on anesthesia capacity was not envisaged, beyond the limited measures included in the chosen surgical capacity assessment tools. However, the initial data analysis revealed the finding that anesthesia was the biggest rate limiting step in surgical care in the studied countries, hence the decision to focus the first empirical publication of the SURG-Africa project on anesthesia. The research team does not include anesthesia specialists, which contributed to the limited scope and depth of the analysis and interpretation of the findings. This manuscript reports the post hoc analysis of findings related to anesthesia capacity of district hospitals collected as part of this situation analysis.

Methods

Ethical approval

Prior Ministry of Health approval for data collection and informed audio-recorded consent for interviews from respondents were obtained. All approving Research Ethics Committees (REC) waived the requirement for written informed consent. Ethical approval was granted by the REC of the Royal College of Surgeons in Ireland, the project consortium lead, under approval no. REC 1417. In the implementation countries ethical approval was received from the College of Medicine Research Ethics Committee in Malawi (approval no. P.05/17/2179), the University of Zambia Biomedical Research Ethics Committee (approval no. 005-05-17), the Kilimanjaro Christian Medical College Research Ethics and Review Committee (approval no. CRERC 2026) and the National Institute for Medical Research in Tanzania (approval no. NIMR/HQ/R.8a/Vol. IX/2600).

Study design

A convergent mixed-method approach was used to provide a systematic, in-depth understanding of the current state of anesthesia care at DLHs and reported according to the GRAMMS standards[20]. A description of the study is presented in the following paragraphs, in line with applicable SAMPL, STROBE and reporting guidelines [21,22].

Data collection

To our knowledge, prior to this study no reliable cross-country district level data on anesthesia were available for any of the three countries involved[13]. A custom-made data collection tool-kit, comprising qualitative and quantitative instruments, was developed by the research team for this study.

Firstly, the Personnel, Infrastructure, Procedures, Equipment and Supplies (PIPES) cross-sectional survey was used to assess availability of the respective elements of surgical capacity[23]. Several studies have endorsed PIPES as a valid and reliable measure of surgical capacity in resource-constrained settings [23,24]. We performed a post hoc analysis of the data collected in 2017 looking specifically at anesthesia capacity. Based on the WHO-WFSA International Standards for Safe Practice of Anesthesia [25], we selected 27 out of 105 PIPES items that pertain to the provision of anesthesia care (Supplemental Table 1). For each country, an anesthesia-specific capacity score was computed at facility level, using the same algorithm as for the overall PIPES. This score ranges from 0 to infinity, because questions about availability of staff and operating rooms have no maximum value[23]. Higher scores are indicative of higher capacity levels. This allows for comparisons across hospitals, countries and over time.

Secondly, in order to validate and expand the information collected through PIPES, a complementary tool was created which comprised closed and open-ended questions, addressing previously published shortcomings of PIPES[18]. It also added other relevant domains such as: self-reported readiness to provide surgical and anesthesia care, referral patterns, availability of NPCs/NPAPs, and data management and quality control measures.

Thirdly, as part of the data collection qualitative semi-structured interviews were conducted using a qualitative case study approach[26] to explore and triangulate the quantitative data, and to gain a deeper understanding of gaps in anesthesia systems at district level. Questions were derived based on the previous experience of the research team working with district hospitals in the study countries [8,27] and a review of relevant literature. All tools are in the Supplemental Text 1.

The custom-made tool-kit was piloted at selected sites in Zambia in July 2017, and adjusted prior to its wider use in all three countries. Data collection took place from July to November 2017. The detailed study design and sampling strategy have been reported in a dedicated publication[28]. SURG-Africa researchers visited some of the sampled hospitals: Malawi 13 DLH visits, Tanzania 8, Zambia 14; and collected data from the remaining ones at workshops organized by the project (Malawi 9 DLHs, Tanzania 22 DLHs, Zambia 10 DLHs).

To complete the PIPES and the complementary tool, a minimum of two key surgical team representatives were surveyed per facility in order to maximize the validity and reliability of the answers provided, as well as to minimize recall bias (Table 1) [29]. The survey was conducted in English . Questions were read aloud by full time project researchers (JG, CP, AJ, GM, MC), including both local and international, and the respondents were asked to discuss each item and provide an agreed response. In some cases the local researchers used the local vernacular to explain or clarify questions. In each country a sub-sample of DLHs was randomly selected for interviews with surgical, anesthesia and nursing staff (Table 1). No participant refused to be interviewed. The qualitative interviews were conducted in each country until data saturation was achieved; all were conducted in English, audio-recorded and later transcribed.

Analysis

For the quantitative data analysis, descriptive statistics were computed, and a two-tailed ANOVA test was used to explore differences and cross-country comparisons in the PIPES index score using SPSS-IBM v24. A thematic analysis was carried out for the qualitative data, using a top-down approach [30]. Two project researchers (JG, CP) jointly designed a data coding framework, based on review of the literature and previous experience in conducting qualitative studies with district level surgical providers[8,27]. Firstly, the researchers coded the data using the coding framework. Additional codes were developed in the second round of analysis. Thirdly,

the codes were grouped into themes and presented to the wider team of researchers to agree the final structure of the analysis.

Results

A total of 76 district level hospitals were included in the study, covering: almost all of Malawi (22 out of 24 government district hospitals in the country), the Northern Zone in Tanzania (30 out of 35 district hospitals in the Northern Zone); and Zambia (24 out of 99 district hospitals in the country) (Table 1).

Table 1. Number of hospitals and cadres included in the mixed-methods study

x

Anesthesia capacity score

Malawi scored the lowest on the modified PIPES anesthesia index score (M = 7.96, SD 1.05), followed by Zambia (M = 8.25, SD = 0.91). Tanzania scored the highest, on average, but had the biggest differences between hospitals (M = 8.34, SD 1.64). Differences between countries were not statistically significant F(2,73)=0.59, p=0.59.

In the qualitative analysis, anesthesia capacity to ensure the delivery of adequate surgical services was not considered sufficient by majority of the respondents. When asked about the main operating theatre (OT) challenges, approximately one third of hospitals in the sample reported issues related to anesthesia (number of skilled staff, equipment or supplies) as the primary problem in the provision of safe surgical care. The analysis of individual PIPES items in the following sections provides further details on the situation in each country.

Personnel and Skills

On average there were two anesthesia providers per hospital in Malawi (range 1 to 4) and in Tanzania (range 0 to 4); and one in Zambia (range 0 to 2) (Table 2). According to survey

responses, anesthesia care at district level is delivered by NPAPs: in Malawi anesthesia was administered exclusively by Clinical Officers (COs) (with formal training in anesthesia), in Zambia by a combination of COs (with formal training in anesthesia) and nurse anesthetists (formally trained in anesthesia), and in Tanzania mainly by nurse anesthetists (formally trained in anesthesia). None of the surveyed district hospitals had anesthesiologists.

Table 2. Number of trained anesthesia and surgical providers at district hospitals by country

X

When comparing anesthesia and surgical staff numbers, the situation in Malawi was the worst with on average of one anesthetist for every 8 surgical providers (mean ratio 1:8), followed by Tanzania (mean ratio 1:4). Zambia had a relatively better ratio of 1:2; however, 7 of 24 sampled hospitals in Zambia did not have any qualified anesthesia provider. In these facilities anesthesia was provided ad-hoc by other staff members who had received on-the-job orientation and had no formal anesthesia training.

The qualitative findings showed that the low numbers of trained anesthesia providers had negative repercussions on hospitals' capacity to maintain essential surgical services. Some hospitals reported that priority was given to emergency cases, neglecting or postponing general elective cases. Others, especially in Zambia, were not able to manage emergency patients either (see Table 3).

Table 3. Anesthesia capacity at district level hospitals

X

The service gaps created by the insufficient number of anesthesia staff were covered, in some cases, by other members of the surgical team, but this practice was considered risky, as explained by one interview respondent:

'(...) if the anesthetist is on leave, one of us has to act as an anesthetist. So meaning shifting responsibility. And the one who is shifting may not have the expertise of anesthesia. So we just have the basic knowledge. Adverse events happens [...], not having capacity to deal with that adverse event.' (DLH4_Medical licenciate_Zambia)

In hospitals where task-sharing was not possible, staff could work extended hours to ensure continued access to anesthesia care for patients. The tiredness and decrease in concentration caused by working overtime were also associated by study participants with increased risks of adverse events.

'(...) the anesthetists, currently we have two. That one is working day and night when the other has to be off duty. So, imagine working day and night'. (DLH1_Nurse_Malawi)

Hospitals where adequate and continuous anesthesia cover could not be guaranteed, especially at night, or when only one anesthetist was available to deal with the caseload, had no alternative but to refer some patients to other health facilities.

Another challenge reported by the surveyed facilities was the different level of training and uneven skills between surgical and anesthesia cadres (Table 4). This was a problem particularly in Malawi, where all but one participant mentioned it. The mismatch in capacity between surgical and anesthesia providers contributed to referrals for certain procedures that could otherwise have been handled locally.

Table 4. Most frequently reported obstacles to anesthesia service delivery by country

x

Respondents highlighted the need for further training, and refresher training of already practicing clinicians, as essential to maintain the skills levels of the different cadres, especially in anesthesia, and to ensure better teamwork and support in the operating theatre.

'(...) *if the anesthesia provider could be sent for pediatric anesthesia* [training] *because to handle pediatric* [cases] *on your own becomes difficult.' (DLH4_Anesthetist_Malawi)*

'I don't do pediatric cases. I am comfortable giving anesthesia, but the surgeon is not. When you don't do something for a long time you tend to forget, so I would need some refresher course'. (DLH9_Anesthetist_Zambia)

In addition to limited personnel availability and skills, respondents also mentioned poor staff motivation, compounded by low levels of confidence, as factors impacting on anesthesia provision.

Better training and increasing the number of qualified anesthesia providers at district hospitals were considered as priorities in the immediate future. A respondent described how the recent arrival of a trained anesthetist improved the hospital's capacity to deliver surgical services and improved operating theatre productivity.

'*we can see that compared to last year we did more cases this year (...) because now we have a qualified anesthetist who was not there before*' *(DLH5_Medical Licenciate_Zambia).*

However, respondents believed that for these solutions to be sustainable, attention must be given to staff retention, as well as deployment, policies, as high staff turnover rates at district hospitals contribute to the challenges.

'Some [staff members] *they come and they go. They say there are no motivators [...] They want to seek greener pastures outside.' (DLH3_Anesthetist_Malawi);*

'So many people they come, they look at the area, they say I can't stay long.' (DLH1_Medical Licenciate_Zambia).

Availability of essential infrastructure, equipment and supplies

An overview of availability of essential infrastructure, equipment and supplies for the provision of anesthesia across the three study countries is presented in Table 5, which reports relevant PIPES items. Infrastructure shortages were the most frequent in Malawi, where almost 70% of hospitals had no reliable access to running water and only one in five DLHs (23%) had uninterrupted access to external electricity, often lacking a backup generator (in nearly half of DLHs). Supply of compressed oxygen was also a common problem, lacking in around a third of surveyed hospitals across the three countries. Other pieces of equipment were also not generally available, with pediatric oropharyngeal airway and endotracheal tubes most frequently missing.

Around one third of the sampled hospitals across all three countries reported not having anesthetic machines always functioning. Additionally, respondents reported that available machines were old and often malfunctional.

'*...we are still using an old machine, the manual one, which usually would require some assistance from someone.' (DLH2_Anesthetist_Zambia*)

'the anesthetist machine is not working, what works is just the small monitor." (DLH3_Anesthetist_Malawi)

In hospitals where anesthesia machines were functional, respondents also reported problems with their numbers, especially in places with multiple operating theatres and only one machine available.

'we also have one anesthetist working machine so it makes it sometimes difficult if you want to be using both theatres, operating rooms, but one working machine.' (DLH1_Clinical Officer_Malawi)

The anesthetic machine is either moved from one theatre to another as needed or, when this is not possible, the additional theatres are simply not used. This practice was reported as having negative consequences on the productivity of these hospitals as their potential surgical capacity was not fully utilized.

Table 5. Number of hospitals with essential infrastructure and equipment for administering anesthesia always available

x

As shown in Table 5, all anesthesia types are generally provided, with ketamine being the most common. Ketamine is offered as standard in all hospitals in the study countries, and sometimes as a necessary alternative when other types of anesthesia are not available.

(...) but if we don't have it [spinal] *then we do alternatives. We have been using ketamine, which is readily available most of the time. (DLH2_Anesthetist_Zambia*)

Improvisation was, in fact, a common theme across the surveyed hospitals, as many reported having to rely on what was available at the time of the operation in order to manage cases. The supply of anesthesia medications, in particular, was reported by interviewees as a problem, impairing hospitals' anesthesia capacity (Table 4). There were inefficiencies in the supply chain (e.g. delays in provision, limited range of drugs to cover different procedures, etc.) and poor quality of products used. Some DLHs representatives expressed concerns that the quality of anesthesia medications ('*ancient drugs*' reported to be in use in Tanzania) can cause complications for patients.

'(...) then you see the management of complications arising from these drugs causes more complications.' (DLH1_Surgeon_Tanzania).

This was especially an issue when treating patients with unstable clinical conditions or '*very sick patients'* (as described by respondents), whose status may deteriorate as a result of the poor quality of the anesthetic medications. An absence of basic medications (e.g. ketamine, propofol or thiopentone) or their poor quality, as reported by some respondents, substantially limited the capacity of a hospital to deliver safe surgical care [31].

Limited availability of anesthesia medications or lack of functional anesthetic machines prompts DLHs to refer simple cases that should be handled locally to other healthcare facilities. *'...at times we refer patients unnecessarily mainly because we don't have an anesthetist who is available and able to provide that type of anesthesia.' (DLH8_Medical Doctor_Zambia).*

Discussion

This paper reports some dimensions of anesthesia capacity in a large sample of DLHs in Malawi, Tanzania and Zambia, filling a critical knowledge gap in the process of scaling-up safe surgery in SSA[9,32]. The focus is on the district hospital, the primary provider of essential surgical and anesthesia care for the vast number of people living outside of urban areas [4]. This is also the level where such services should be offered in a safe and affordable way [32].

Challenges in district hospital anesthesia staffing, equipment and supplies in SSA are well documented in the literature [1,15,33,34] but, as suggested by our evidence, may benefit from an in-depth exploration to fully understand impact as well as to devise context specific responses.

At first glance, most DLHs in our study (self-)reported having basic staff, equipment and supplies to deliver anesthesia and overall capacity, as measured by the anesthesia PIPES scores, was similar across the three countries. However, our qualitative analysis showed that these crude measures were somewhat misleading. Firstly, when comparing results with the guidelines in the WHO-WFSA International Standards[25] none of the surveyed DLHs met international minimum safety standards. Secondly, an in-depth investigation into individual PIPES components brought to light major cross-country differences.

Specifically, shortage of anaesthesia providers seems to be particularly problematic in Zambia. Some hospitals did not have trained anesthesia providers at all, which greatly increases risks for patients[35]. Therefore, the 1:2 anesthesia to surgical providers ratio should not be regarded as a positive finding; it resulted from low numbers of surgical providers compared to the other two countries. This manpower problem, as documented also in other studies[27], was aggravated by difficulties in retaining existing staff due to factors such as poor working and living conditions at district hospitals; and more lucrative positions in the private or NGO healthcare sector, and/or in urban areas[27,8]. Opportunities for continuous training and career growth, provision of financial incentives and good social services have been proposed as retention strategies [1].

Non-availability of supplies and equipment were among the most frequently reported challenges in Malawi. Basic infrastructure, such as water and electricity, was not reliable in around two thirds of surveyed DLHs, even if the situation has improved in recent years[36]. Malawi had the highest numbers of anesthesia providers per hospital in our sample, but these figures need to be treated with caution. While staff numbers were relatively high, overall skills levels were reported as generally poor and not matching the skills level of surgical providers. As supported by other studies, raw staff numbers may not reflect actual capacity to deliver surgical services and surgical outputs[37]; other factors such as skills, confidence and motivation

also affect performance of surgical teams[8]. Previous research has proposed that skills, confidence and attitudes of district clinicians may be improved through supervision[8,16].

Northern Tanzania faces multiple challenges, but in our study no individual factor stood out. Regional anesthesia blocks were reported as not done in one third of surveyed facilities in Tanzania, unlike Malawi and Zambia where they were reported as commonly done. However, this finding needs to be treated with caution, because the question in the PIPES tool did not clearly define regional blocks, making interpretation difficult. Also, availability of anesthesia machines was lowest in Tanzania compared to Zambia and Malawi, with reports of old and frequently faulty machines. This critical shortage has been acknowledged in the Tanzania National Surgery Obstetric and Anesthesia Plan (NSOAP) and the government has prioritized the need for functioning anesthesia machines, training on how to operate them, as well maintenance plans [19].

An important finding from our study is that deficits at district level, especially in anesthesia, are driving unnecessary referrals of patients needing basic surgical interventions. This is a major issue for the rural communities served by district hospitals, as access to surgical care in these locations is already limited and distance from alternative and referral health facilities may be considerable. Further research is needed to estimate the additional financial burden this situation causes, both for healthcare systems and patients. Lack of qualified anesthesiologists has forced the three countries in our study to adopt 'task-shifting' strategies, but evidence of the safety of this solution is needed[12].

One last key finding that emerged from this investigation is methodological. Research relying only on quantitative measurements does not provide the full picture of the actual situation on the ground, because they focus on 'taking stock' of available resources, without exploring what impact identified shortages could have. Although this capacity assessment study cannot claim

that it identified the breadth of issues related to anaesthesia capacity in the studied countries, the use of a mixed-methods approach has provided useful, additional insights. Such methods seem to be the most appropriate, because they explore both the 'hard' and the 'soft' dimensions, not only measuring 'how much' but also exploring the 'why and why not' dimensions of the capacity to deliver safe surgery and anesthesia.

This study has limitations. Firstly, the capacity to deliver safe anesthesia formed one module within a broader tool and approach to measure and explore safe surgery. Hence, we included in the post hoc analysis only items that pertained to minimum standards of anesthesia provision as described by WHO-WFSA[25]. The used tools was not designed to measure anesthesia capacity, so the results need to be treated with caution. While one cannot draw comprehensive conclusions about anesthesia capacity in the studied hospitals, the findings unveil some aspects of anesthesia deficits at district level which would benefit from further investigation. There is a need for more in-depth studies using anesthesia-specific tools. There is also a need to develop a more targeted instrument that would allow the measurement of anesthesia capacity over time - ideally through an index score.

Secondly, there are limits to generalizing results nationwide in Tanzania, where the study was conducted only in the Northern Zone (5 regions); and in Zambia, where a representative sample of DLHs from five of ten provinces were included. Thirdly, because this study was not originally planned to focus on anesthesia capacity, the respondents included in the sample comprise various members of surgical teams. Limited representation of anesthesia providers in the sample could have impacted on the accuracy and reliability of the data collected.

Conclusions

More than a decade ago, the recommendation was made that anesthesia services in LMICs need to be better recognized within national healthcare budgets, and that the basic requirements for safe anesthesia need to be prioritised[38]. As our results show, the reality of anesthesia care at district level in Malawi, Tanzania and Zambia falls far short of this modest and essential, life-saving goal. The evidence in this paper supports the case for the studied countries to invest in educational programs to train, retrain and retain anesthesia providers at all levels[39]. More efforts should be invested in assuring that supply chains for anesthesia care are operational and easily accessible by district facilities; and that hospitals are provided with relevant equipment together with maintenance plans. The findings in this paper go some way towards highlighting the critical importance of anesthesia capacity, which is (or should be) at the heart of Surgical Obstetric Trauma and Anesthesia responses to meet the needs of neglected rural populations in sub-Saharan Africa. Global policy makers and funding bodies need to prioritize anesthesia and surgical care, ensuring that skilled staff, infrastructure and supplies are in place, because injury and surgically treatable conditions kill more humans currently than TB, HIV and malaria together, while the latter three receive the majority of funding [40].

Supplemental material:

Supplemental table 1. WHO-WFSA International Standards for a Safe Practice of Anaesthesia vs PIPES items selected for the presented analysis.

EQUATOR Checklist

Supplemental text 1. Data collection instruments used to collect data for the presented study.

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Table 1

Table 1. Number of hospitals and cadres included in the study

	Quantitative survey (PIPES)			Qualitative interviews		
	Malawi	**Tanzania**	**Zambia**	**Malawi**	**Tanzania**	**Zambia**
Number of hospitals per country	**N=22**	**N=30**	**N=24**	**N=9**	**N= 12**	**N=12**
Number surgical provider participants (MD or NCP)	19	33	24	5	5	10
Number of anesthesia provider participants (NPAP)	16	20	7	4	5	3
Number of participating nurses working in operating theatre (general or formally qualified)	14	17	18	3	2	3
Total	49	70	49	12	12	16

Table 2

Table 2. Number of trained anesthesia and surgical providers at district hospitals by country

	Malawi					Tanzania					Zambia				
	Tot	**Min**	**Max**	**Mean**	**SD**	**Tot**	**Min**	**Max**	**Mean**	**SD**	**Tot**	**Min**	**Max**	**Mean**	**SD**
Anesthesia providers	48	1	4	2	0.66	68	0	4	2	0.94	24	0	2	1	0.78
Surgery providers	364	9	31	17	6.42	265	2	24	9	4	88	1	8	4	1.62

Table 3

Table 3. Anesthesia capacity at district level hospitals

	Malawi N=22(%)	**Tanzania N= 30(%)**	**Zambia N=24(%)**
Hospitals with an anesthesia provider formally trained in anesthesia	22 (100%)	29 (96.7%)	17 (70.8%)
Hospitals reporting full anesthesia capacity to deal with all surgery cases expected to do	16 (73%)	9 (30%)	11 (46%)
Hospitals with an anesthesia provider always available for elective surgery	18 (82%)	28 (93%)	15 (63%)
Hospitals with an anesthesia provider always available for emergency surgery	21 (96%)	27 (90%)	14 (58%)

Table 4

Table 4. Most frequently reported obstacles to anesthesia service delivery by country[a]

N of hospitals in qualitative study that reported issues with:	Malawi N=9 (%)	Tanzania N=12 (%)	Zambia N=12 (%)
Skills	8 (89%)	8 (67%)	2 (17%)
Anesthesia machine	4 (44%)	9 (75%)	2 (17%)
Staffing	3 (33%)	6 (50%)	10 (83%)
Availability of anesthesia drugs	2 (22%)	6 (50%)	3 (25%)

[a]Data from semi-structured interviews. Responses not mutually exclusive, more than one possible answer.

Table 5

Table 5. Number of hospitals with essential infrastructure and equipment for administering anesthesia always available[a]

	Malawi N=22 (%)	**Tanzania N= 30 (%)**	**Zambia N=24 (%)**
Infrastructure			
Running water	7 (32%)	25 (83%)	16 (66%)
External electricity	5 (23%)	26 (87%)	18 (75%)
Backup generator	12 (55%)	27 (90%)	16 (67%)
Oxygen: compressed (cylinder)	13 (59%)	20 (67%)	18 (75%)
Oxygen: concentrator	20 (91%)	26 (87%)	19 (79%)
Monitoring			
Pulse oximeter	21 (96%)	25 (83%)	23 (96%)
Stethoscopes	22 (100%)	29 (97%)	22 (92%)
Thermometer	16 (73%)	30 (100%)	23 (96%)
Blood pressure	20 (91%)	27 (90%)	23 (96%)
Anesthesia equipment			
Anesthetic machine	16 (73%)	18 (60%)	20 (83%)
Oropharyngeal airway (adult size)	20 (91%)	24 (80%)	23 (96%)
Oropharyngeal airway (pediatric)	16 (73%)	21 (70%)	20 (83%)
Facemasks	20 (91%)	23 (77%)	21 (88%)
Endotracheal tubes (adult)	20 (91%)	23 (78%)	21 (88%)
Endotracheal tubes (pediatric)	17 (77%)	19 (63%)	17 (71%)
Resuscitator bag and valve mask (adult)	22 (100%)	26 (87%)	24 (100%)
Resuscitator bag and valve mask (pediatric)	20 (91%)	26 (87%)	22 (91%)
Anesthesia disposables			
IV infusion sets	18 (82%)	25 (83%)	22 (92%)
IV cannulas	20 (91%)	25 (83%)	22 (92%)

Syringes	21 (96%)	26 (87%)	22 (92%)
Disposable needles	21 (96%)	24 (80%)	23 (96%)
Anesthesia procedures			
Regional anesthesia blocks	18 (82%)	19 (63%)	19 (79%)
Spinal anesthesia	22 (100%)	29 (97%)	23 (96%)
Ketamine anesthesia	22 (100%)	30 (100%)	24 (100%)
General anesthesia	22 (100%)	28 (93%)	19 (79%)

[a]Anesthesia PIPES tool data