World J Surg (2019) 43:1185–1192
https://doi.org/10.1007/s00268-019-04911-5

ORIGINAL SCIENTIFIC REPORT

Identifying Information Gaps in a Surgical Capacity Assessment Tool for Developing Countries: A Methodological Triangulation Approach

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Published online: 18 January 2019

Abstract

Background Surgical capacity assessment in low- and middle-income countries (LMICs) is challenging. The Surgeon OverSeas' Personnel Infrastructure Procedure Equipment and Supplies (PIPES) survey tool has been proposed to address this challenge. There is a need to examine the gaps in veracity and context appropriateness of the information obtained using the PIPES tool.

Methods We performed a methodological triangulation by comparing and contrasting information obtained using the PIPES tool with information obtained simultaneously via three other methods: time and motion study (T&M); provider focus group discussions (FGDs); and a retrospective review of hospital records.

Results In its native state, the PIPES survey does not capture the role of non-physician clinicians who contribute immensely to surgical care delivery in LMICs. The surgical workforce was more accurately captured by the FGDs and T&M. It may also not reflect the improvisations (e.g., patients sharing beds, partitioning the operating theater, and using preoperative rooms for surgery, etc.) that occur to expand surgical capacity to overcome the limited infrastructure and equipment.

Conclusions The PIPES tool captures vital surgical capacity information but has gaps that can be filled by modifying the tool and/or using ancillary methodologies. The interests of the researcher and the local stakeholders' perspectives should inform such modifications.

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Introduction

The United Nations' (UN) Post-2015 Sustainable Development Goals place emphasis on achieving universal health coverage (UHC) [1, 2]. The UN World Health Assembly resolution 68.15 recognizes "strengthening emergency and essential surgical care and anesthesia as a key component of UHC" [1–3]. To achieve UHC, there is a need to improve surgical capacity and delivery in low- and middle-income countries (LMICs) [3–5]. However, over 70% of the world lacks access to safe, basic lifesaving surgery [6–8]. The majority of the global unmet surgical need is concentrated in sub-Saharan Africa (SSA), where most countries have limited capacity to tackle the growing burden of surgical disease [9]. Correspondingly, about 93% of individuals in SSA do not have access to essential surgery [7].

Robust surgical capacity assessment is crucial to identifying and addressing surgical capacity gaps and challenges of LMICs. Standardized metrics for surgical capacity assessment and global surgical surveillance are the cornerstones of quality improvement and policy formulation efforts [10, 11]. The findings from such tools also form the evidence base for the development of National Surgical, Obstetric, and Anesthesia Plans, which influence political prioritization of surgical issues in LMICs [12].

Although tools exist to assess surgical capacity in LMICs, evidence shows that existing tools do not accurately reflect surgical health systems and output [13]. The Surgeon OverSeas' Personnel Infrastructure Procedures Equipment and Supplies tool (hereafter referred to as "PIPES"), a modification of the World Health Organization's (WHO) Integrated Management of Emergency and Essential Surgical Care (IMEESC) toolkit, has gained prominence as a surgical capacity assessment tool for LMICs [14, 15]. It estimates surgical capacity based on the availability of resources in five domains: personnel, infrastructure, procedures, equipment, and supplies. The information elicited from PIPES is used to calculate a PIPES score and index, which quantitatively reflects a health facility's surgical capacity [15].

Triangulation is a technique used to validate data by cross-verifying data from more than one source [16, 17]. Methodological triangulation entails using different methods to study a specific phenomenon [18]. Triangulation offers broader, deeper, and more accurate insights into the phenomenon being investigated. It helps the researcher overcome the limitations and intrinsic biases associated with single-method or single-observer studies.

Using a regional referral hospital in rural Uganda as a case study, this study employs a methodological triangulation approach to evaluate the veracity of data elicited via PIPES by identifying the strengths and information gaps in PIPES relative to three other methods used simultaneously for evaluating surgical capacity in the same facility. PIPES and similar quantitative tools are often designed to evaluate the presence or absence of specific human and physical resources. We hypothesize that PIPES may provide an incomplete picture of surgical capacity in LMICs that may detract from our understanding of surgical capacity.

Methods

Study setting

This study was carried out at the Soroti Regional Referral Hospital (SRRH), which serves eight districts and an estimated two million people in rural northeastern Uganda [19]. It is the highest level facility in the region and receives referrals from health centers and district hospitals in the region and neighboring districts.

Study instruments and approach

From May 1 through June 23, 2015, we conducted PIPES; a time and motion study (T&M), which involved directly observing and recording the processes involved with surgical care delivery; focus group discussions (FGDs) with local providers to ascertain the barriers and facilitators of surgical capacity and delivery; and a retrospective review of hospital records [20].

First, we conducted PIPES by purposively interviewing a general surgeon who was formerly the hospital director, because he/she had extensive knowledge about resource availability and limitations. Second, we used a T&M approach to directly observe the processes of emergency surgical care from patient admission until the definitive intervention was instituted. The resources, interventions, time of interventions, gaps in surgical care delivery, and causes of gaps were noted. Third, using a semi-structured interview guide, we conducted FGDs with healthcare providers to identify barriers and facilitators of surgical care delivery. The key constructs that were explored in FGDs included barriers to and facilitators of quality surgical care delivery at SRRH and possible interventions to improve surgical capacity at SRRH. Providers were placed in one among these groups: consultant surgeons, administrative staff, nurses, or intern doctors. Interviews were conducted in English as all providers were fluent in English. Interviews were recorded, transcribed, and subsequently coded and thematically analyzed using the grounded theory framework. Finally, we conducted a retrospective review of hospital records (ward logbooks, theater logbooks, and nurses' record book) to identify patient volume, past

surgical interventions, hospital resource utilization by patients, and surgical workforce at SRRH. The study instruments and data collection approach used in this study have been described previously [19].

Data triangulation

With the information elicited from the above methodologies, we investigated the gaps, veracity, and appropriateness of the information obtained via PIPES by using a data triangulation approach. This entailed comparing and contrasting the information elicited from PIPES against the information obtained from the other three methods with a focus on the data pertaining to surgical workforce, infrastructure, procedures, equipment, and supplies. We identified points of data convergence and divergence. We explored points of data divergence further to isolate the reasons and potential implications. Findings were expressed using data triangulation tables.

Results

We identified points of divergence and congruence among the findings of PIPES and other methods.

Personnel

PIPES captured four cadres of surgical providers (Table 1), while FGDs and T&M captured the same cadres plus intern doctors, urologists, clinical officers, and orthopedic officers. During T&M, there were no anesthesiologists at SRRH; nurse anesthetists provided anesthesia care. While PIPES, FGDs, and T&M showed the number of surgical providers per cadre (Table 1), only FGDs and T&M provided further information regarding the adequacy of the estimated surgical workforce (Table 2).

Infrastructure, equipment, and supplies

PIPES, FGDs, and T&M all highlighted severe gaps in surgical infrastructure, equipment, and supplies. Other methods yielded complementary information that provided context and further insight into findings of PIPES (Table 3). Nonetheless, there were some differences in the information obtained regarding hospital bed capacity and operating theater.

For instance, PIPES only reflects the overall number of beds in the hospital. However, retrospective review of hospital logs together with T&M shows that patient volume in the male and female surgical wards exceeded bed capacity 83% and 63% of the time with a median occupancy rate of 134% and 120%, respectively [19], which differed from the inferences that could be made from the findings of PIPES (Table 3). FGDs showed that fracture patients who were being treated with long-term traction took up the majority of available hospital bed space, displacing other patients.

Per PIPES, SRRH has one operating theater. The T&M, however, shows that providers at SRRH have improvised to expand their operating capacity by dividing the operating room into two with an examination screen and operating table on each side. Furthermore, the corridor, sterile linen room, and the preoperative/postoperative room also have operating tables that are used for surgeries. This arrangement allows for five simultaneous surgeries. Although chest tubes were reportedly unavailable, local providers improvised using a nasogastric tube, taped to a half-filled plastic bottle of commercial water, to create an underwater seal chest drainage apparatus. Other improvisations include the use of gloves and Foley catheters as drains.

Procedures

About 90% of surgical procedures listed in PIPES were always available at SRRH, excluding open fracture treatment, laparoscopic surgery, cleft lip repair, and club foot repair. Hospital records confirmed the availability of the same and other surgical procedures including urological procedures (e.g., prostatectomy, gender correction surgery) but were beyond the scope of PIPES. The T&M revealed that despite staff having the skills to perform 90% of the surgical procedures, patients often experienced significant delays or were unable to access some of the 36 available surgical procedures for other reasons, which was not captured by PIPES (e.g., the unavailability of certain equipment and supplies prevented patients from obtaining surgical care that would otherwise be available at SRRH). Some of these were captured by the FGDs, e.g., "There are instances whereby we have a senior consultant to offer that specialized service but the right equipment is unavailable *(FGD004)*." "You can't appropriately manage the patient because they don't have adequate space. On a bed where you should manage one patient, you have two or three… (FGD001)."

Discussion

Our findings suggest that PIPES is useful for screening for the availability of surgical resources and interventions (see Table 4 for a compilation of our recommendations); however, it is not necessarily comprehensive when used in isolation. Further, a well-designed mixed-methods approach built around PIPES can provide complementary

Table 1 Number and cadres of health providers involved in surgical care delivery as detected by each methodology

Theme/topic of interest	Information elicited by each study methodology			
	PIPES survey	Provider focus group discussions	Time and motion study (direct observation)	Retrospective review of clinical records
Surgical workforce	4 Nurse anesthetists	4 Nurse anesthetists	4 Nurse anesthetists	Nurse anesthetist*
	0 Anesthesiologist	0 Anesthesiologist	–	–
	6 Medical doctors (that perform surgery)	1 Medical officer	1 Medical officer	Medical officers*
		5 Intern doctors	5 Intern doctors	Intern doctors*
	2 General surgeons	2 General surgeons	2 General surgeons	General surgeons*
	–	1 Urologist	1 Urologist	Urologist*
	–	4 Orthopedic officers	4 Orthopedic officers	Orthopedic officers*
	–	5 Clinical officers	5 Clinical officers	Clinical officers*

"*" Exact number not available

"–" Information not captured by methodology

Table 2 Data triangulation: ability of each methodology to estimate the adequacy of surgical workforce

Methodology	Adequacy of the number of providers to meet the surgical demand at SRRH
PIPES survey	The PIPES tool gives the numerical count of each cadre of providers, but there is no rate, denominator, or comparator to reflect the adequacy of the workforce. For example, "There were 2 general surgeons at SRRH"
Focus group discussions	Providers gave insight into the adequacy of the surgical workforce using a specific metric (patient/provider ratio), e.g., "… when you look at the patient to health worker ratio, especially the doctors, you find that it is very very high. You find that you are inundated by many patients and so that is going to affect your contact time with the patient … that also cuts down the quality of the healthcare that you are providing because there are so many patients and the health workers are a bit too few (FGD001)"
Time and motion study	Providers were overwhelmed by the local surgical demand, and some patients are unable to access surgery in a timely manner or altogether
	The beds were often full; patients shared beds and slept on the floor or outside the wards
Retrospective review of clinical records	The patient number of surgical patients often exceeded the available resources at SRRH, e.g., The average surgical inpatient occupancy rates were 134% and 105% for males and females, respectively

data and give a holistic, context-appropriate assessment of surgical capacity that more completely captures surgical care delivery in LMICs. Each method served to corroborate information from the other.

We identified specific issues for which PIPES provides incomplete information. Therefore, assumptions and interventions that are based only on such findings may be limited. To optimize the accuracy and validity of study findings, the researcher may consider incorporating the perspective of local providers in the planning, implementation, and interpretation of findings. The researcher may have to modify PIPES in order to capture context-specific information (e.g., role of clinical officers) [21], specialty-specific information (e.g., neurosurgical capacity) [22], and/or disease-specific information (e.g., obstetric fistula). It may also be beneficial to couple PIPES with other surgical capacity assessment tools [23] or methodologies [19] that explore dimensions of surgical capacity assessment that are relevant to the researcher.

A surgical workforce count, as used in PIPES, may be valuable, but it is difficult to make inferences regarding surgical workforce adequacy without a denominator to aid the interpretation of the adequacy of workforce count. An estimate of the surgical workforce relative to the surgical patient volume or the population within the hospital's catchment area may offer deeper insight into the adequacy of the surgical workforce capacity. The additional information (i.e., surgical inpatient volume, population of the catchment area that the hospital covers, etc.) required to make the estimate of surgical workforce density or adequacy can be obtained via less resource-demanding sources such as hospital records (e.g., surgical outpatient and inpatient records or theater logs) and the Demographic and Health Surveys.

Table 3 Data triangulation table comparing information from PIPES with other sources

Theme/topic of interest	Information elicited by each study methodology		
	PIPES survey	Focus group discussions	Time and motion study
Infrastructure			
1. Number of beds as a measure of capacity	The hospital has a total of 300 beds	"The capacity of the ward is 18… but we take up to 45 (FGD004)" "… you will get patients sleeping on the veranda of that ward… over 10 of them. Those are patients because there is no space inside; they opt to sleep on the veranda (FGD4)"	Male / Female Number of beds: 33 / 20 Number of patients: 20–62 / 10–30 Median occupancy rate: 134% / 120% Frequency at which bed space is exceeded: 83% / 60% Patients shared beds and slept on the floor, in storage rooms, or outside the ward
2. Emergency department	Not available	"The challenge here often is that the casualty unit is not well set up. Not well coordinated or facilitated. Not adequate in terms of space, staff number and skills (FDG003)"	The emergency department is not set up so the outpatient department is being used to receive, triage, and treat patients with emergency surgical conditions
3. Pretested blood available and blood bank	Not always available	"An operation here may (if done) be successful… the person to do the operation is there, but the blood is not there so the person is referred due to blood (FGD003)"	Blood was donated at SRRH and sent to Mbale Regional Referral Hospital (MRRH) for screening, and the MRRH would return fewer units of blood than was sent for screening
4. Laboratory to test blood and urine	Not always available	"We have our lab in the hospital working from 8 AM–5 PM, thereafter, they close… with those critical areas closed at night, they leave the physician to look after patients using the best guess (FGD2)"	Throughout the duration of the study, patients with surgical emergencies were asked to go to other nearby laboratories and imaging facilities for blood tests, X-rays, and ultrasound scans and then to return and continue care
5. Functioning X-ray machine	Not always available	"When we come to other units that help theatre like the area of X-Ray, you've seen the nature of X-rays images we are producing. It's a bit of a pain: poor quality and not useful"	
6. Functioning ultrasound machine	Not always available	"…in our setting we don't have that luxury of having emergency investigations: you find we don't have mobile X-rays, we don't have ultrasound ready there"	Emergency investigations ordered at night were not performed until the morning when the laboratory was open. Providers relied on clinic signs
Equipment			
1. Sterilizer	Unavailable	"… in theatre we have a very old ancient autoclave which works on and off… power goes off without warning… sometimes it goes off for 3–4 days… this affects us a lot because you can't sterilize (FGD001)"	Surgeries were delayed because of lack of sterile linen because the autoclave was not working
2. Endoscope	Unavailable	"I think over there (in America) they do mostly endoscopic surgery (for foreign bodies in the esophagus) but here we improvise by using a Foley's catheter, pass it beyond the point of obstruction by the foreign body … inflate it and apply gentle traction as you withdraw it and it works (FGD001)"	An endoscope was not seen at SRRH over the study period

In its native state, PIPES does not capture the role of non-physician clinicians (NPCs), particularly clinical officers, in surgical care delivery. Half of SSA countries rely on NPCs to provide a variety of surgical interventions [24–26]. NPCs perform 92% and 84% of major surgeries in Mozambique and Tanzania, respectively [27, 28]. In East Africa, orthopedic clinical officers perform crucial interventions like fractured limb traction [19]. Surgical nurses also perform surgeries in some settings [29]. However, PIPES only uses the availability of general surgeons, medical doctors, anesthesiologists, and nurse anesthetists to predict surgical capacity and may thus provide an inaccurate assessment of surgical capacity. Researchers may resolve this by modifying the instrument to include non-physician surgeons, as was done by Henry et al. [30].

PIPES identified surgical equipment, supplies, and infrastructure that were always available; however, through direct observation of the process of surgical care and FGDs, we recognized that some of the equipment, listed as available, were not standard equipment but local fabrications or improvisations. Although the quality and safety of these fabrications and improvisations are undetermined, they are critical to surgical care delivery in such settings. For the purpose of identifying resource constraints, capacity assessments should reflect the use of such improvisations. Therefore, conducting PIPES in person, rather than over the phone, may be advantageous and advisable to visualize the available resources and inquire further if necessary. Qualitative interviews may augment PIPES for specific areas of inquiry. Similarly, in high-volume rural facilities like SRRH, surgical demand exceeds available resources; patients often share beds or sleep on the floor, in storage rooms, or outside in the open. This limits the utility of the "number of beds" variable in the general assessment category of PIPES.

This study highlights the importance of understanding the dynamics surrounding the accessibility of available surgical procedures, which often requires a qualitative approach or direct observation. Per PIPES, 36 out of 40 essential surgical procedures are available at SRRH, with the exceptions of cleft lip and palate repair, clubfoot repair, open fracture reduction, and laparoscopic surgeries [19]. FGDs and T&M showed that the overwhelming surgical volume and patient throughput challenges at SRRH denied patients access to available procedures and were more pressing limitations to surgical capacity than the unavailability of surgical procedures; this critical distinction was not and could not have been captured by PIPES. The importance of a qualitative approach is further reflected in the fact that "section C" of the WHO IMEESC tool, from which PIPES was derived, contains a qualitative component that explores the determinants of surgical procedure availability [14].

This mixed-methods study has some notable limitations. While we believe our study has painted a better picture of the surgical capacity at SRRH than any one methodology could on its own, we acknowledge that gaps in our understanding may still exist that could be remedied with the use of other quantitative and qualitative approaches. The retrospective arm of this study captures only a two-month period and may not be generalizable across a whole year. Furthermore, with retrospective studies there is variability in documentation and data quality. However, with data triangulation, gaps in data quality are more readily identifiable and possibly remediable. Direct observation of healthcare processes may lead to the Hawthorne effect, which we attempted to address by delaying data collection until the investigator was well integrated with staff. Finally, applying mixed methods for the assessment of surgical capacity may be relatively time-consuming and

Table 4 Summary of recommendations

Category	Recommendation
General	Use quantitative tools (such as the PIPES tool) for screening the availability of surgical resources and interventions
	Design and use a mixed-methods approach built around quantitative tools (such as the PIPES tool)
	Design quantitative tools with flexibility built into them (such as with the use of scales for responses)
PIPES-specific	Incorporate the perspective of local providers in the planning, implementation, and interpretation of findings of the PIPES tool
	Modify the PIPES tool to capture context-, specialty-, and/or disease-specific information
	Couple the PIPES tool with other surgical capacity assessment tools
	Use less resource-demanding sources such as hospital records and the Demographic and Health Surveys to obtain additional information required to make the estimate of surgical workforce density (to augment the surgical workforce count as determined by the PIPES tool)
	Modify the PIPES tool to include non-physician surgeons
	Conduct the PIPES tool in-person to visualize the available resources and inquire further if necessary

therefore less feasible, due mostly to qualitative methodologies.

Conclusion

While PIPES is good at enumerating resource limitations in health facilities in LMICs, there are other vital aspects of surgical capacity that by design are not captured by PIPES. Qualitative methodologies, including but not limited to the ones we utilized in this study, can provide more content and context, and we recommend using qualitative approaches for assessing surgical capacity in LMICs to complement—not replace—quantitative assessments. The T&M approach, for instance, offers an objective assessment of surgical processes and capacity through the lens of an independent observer and can isolate the barriers to surgical capacity and their impact on surgical care delivery. It also captures the adaptability of providers through improvisations. A well-designed mixed-methods study can provide a robust assessment of surgical capacity. Nevertheless, there are several notable advantages of quantitative approaches that mixed-methods or exclusively qualitative approaches to surgical capacity assessments do not have. For instance, quantitative assessments like PIPES and the WHO tools can provide an understanding of surgical capacity relatively quickly. Alternatively, we recommend that quantitative tools, such as PIPES, can be designed with flexibility built into them.

As the importance of surgery in global health becomes clearer and given the unique nature of surgical systems in LMICs presently, it is important that researchers in the surgical community work to both standardize their capacity assessment tools and protocolize how to adjust them to suit local contexts.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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

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