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Exploring the Relationship Between Surgical Capacity and Output in Ghana: Current Capacity Assessments May Not Tell the Whole Story

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Abstract

Objective—Capacity assessments serve as surrogates for surgical output in low- and middle-income countries where detailed registers do not exist. The relationship between surgical capacity and output was evaluated in Ghana to determine whether a more critical interpretation of capacity assessment data is needed on which to base health systems strengthening initiatives.

Methods—A standardized surgical capacity assessment was performed at 37 hospitals nationwide using WHO guidelines; availability of 25 essential resources and capabilities was used to create a composite capacity score that ranged from 0 (no availability of essential resources) to 75 (constant availability) for each hospital. Data regarding the number of essential operations performed over 1 year, surgical specialties available, hospital beds, and functional operating rooms were also collected. The relationship between capacity and output was explored.

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Results—The median surgical capacity score was 37 [interquartile range (IQR) 29–48; range 20–56]. The median number of essential operations per year was 1480 (IQR 736–1932) at first-level hospitals; 1545 operations (IQR 984–2452) at referral hospitals; and 11,757 operations (IQR 3769–21,256) at tertiary hospitals. Surgical capacity and output were not correlated ($p > 0.05$).

Conclusions—Contrary to current understanding, surgical capacity assessments may not accurately reflect surgical output. To improve the validity of surgical capacity assessments and facilitate maximal use of available resources, other factors that influence output should also be considered, including demand-side factors; supply-side factors and process elements; and health administration and management factors.

Introduction

Healthcare capacity assessments have been used to document baseline availability of resources and capabilities, benchmark capacity improvements over time or after interventions, and plan targeted development activities [1, 2]. Assessments of the surgical capacities of low- and middle-income countries (LMICs) across the globe deficiencies that are assumed to preclude the delivery of safe surgical care; [1] in addition to the functions above, results from these assessments have laid the groundwork for advocacy aimed at increasing and focusing attention, research, and funding toward the gross health inequity that results from insufficient population access to surgical care [1, 3].

Partly as result of this advocacy, the World Health Assembly (WHA) ratified resolution 68.15: ‘Strengthening emergency and essential surgical care and anesthesia as a component of universal health coverage.’ [4] In this resolution, the WHA recognized the need for ‘relevant, meaningful, and reliable measures of safe emergency and essential surgery and anesthesia’ to guide health system strengthening efforts and foster political and public support. Currently, few LMICs have standardized system-wide surgical registries or mechanisms to monitor the burden of conditions that require surgical care; both of which exist for other services and conditions (e.g., TB, HIV, maternal and child health, vaccine-preventable disease) [5]. Therefore, many LMICs continue to rely on assessments of surgical capacity as surrogates for output (or output relative to the population) to determine the potential ability for facilities to provide safe surgical care and potentially meet the needs of their populations [2, 6].

One of the principal surgical capacity assessment tools is the World Health Organization (WHO) Tool for Situational Analysis to Assess Emergency and Essential Surgical Care (TSAEEESC), which, along with complementary WHO guidelines for emergency, surgical and trauma care, has been the model for a number of other locally adapted assessment tools [1, 7–9]. Given the weight that the global surgery community, governments, and health system planners place on these assessments, it is important that they accurately reflect surgical output so that useful decision-making can occur. The tool has demonstrated relatively high inter-rater agreement and reliability over time, namely from studies performed in Ghana [2, 10]. However, there has not been a report that documents the validity of this or other capacity assessment tools; further, no report has examined the relationship between surgical capacity and output (i.e., number of operations performed per year) [10, 11].

To address this gap, we aimed to explore the relationship between surgical capacity and output at hospitals in Ghana. By doing so, we might improve our ability to interpret capacity assessments; more accurate interpretation of assessments and understanding of the relationship between surgical capacity and output will allow better targeting of interventions to improve surgical care delivery.

Methods

Setting

Ghana is a lower-middle-income country in West Africa with a population of nearly 26 million people [12]. Ghana has 10 regions divided into 216 districts. The healthcare system has four levels of care: primary health centers (PHC) and 155 district (first-level), nine regional (referral), and four tertiary hospitals. Most districts have several PHCs, and about 60% of districts have a government or mission hospital that serves as a first-level hospital [13]. PHCs provide basic public health and primary care services; though an important initial site of contact for some surgical patients, these facilities were not assessed as this study focused on hospital-based surgical care. First-level hospitals are staffed by medical officers and nurse anesthetists; these facilities usually offer at least some surgical services and have between 50 and 100 beds [14]. Patients requiring more complex care are transferred, as possible, to one of the referral or tertiary hospitals [15]. In addition to medical officers and nurse anesthetists, referral hospitals are typically staffed by specialist surgical providers (e.g., general, obstetric, and orthopedic surgeons) and contain between 100 and 500 beds. Tertiary hospitals typically offer a broad range of surgical services and have between 500 and 2000 beds.

Capacity assessment

In 2014–15, we performed a nationwide surgical and trauma care capacity assessment to inform targeted health system strengthening activities [14, 16–18]. We used a survey instrument adapted from WHO guidelines (e.g., TSAAEESC, Guidelines for Essential Trauma Care, Generic Essential Emergency Equipment List) [7–9] and The World Bank Disease Control Priorities Project, 3rd Edition (DCP³); [19] these guidelines list resources and capabilities considered to be *essential* or *desirable* at different levels within a healthcare system. ‘Essential’ resources and capabilities are considered most cost-effective, universally applicable, and have the highest potential population impact. The assessment in Ghana examined the entirety of resources and capabilities listed in the guidelines above; however, this study focused on 25 essential surgical resources or capabilities, which served as proxies for surgical capacity more broadly (Table 1). We did not collect data on essential dental, ophthalmologic, oral-maxillofacial, or advanced pediatric surgical capacity; thus, operations typically performed under the auspices of these specialties were not included in the analysis.

Sample strategy

First-level hospitals were purposively sampled to represent those most likely to care for patients with surgical conditions, the diversity of surgical care development, and the variation in geography and local socioeconomics [20]. At least two first-level hospitals in each region (based on region population size) were selected by being: in a populous area, *or*

identified by the respective Ministry of Health Regional Health Directorate as caring for a higher surgical volume than others within the region, *or* designated as a surgical or trauma hospital by the Ministry of Health; *and* outside of an hour's transport to a referral or tertiary hospital. Using these criteria, we sampled 26 first-level hospitals. Referral and tertiary hospitals were exhaustively sampled, save one each that declined participation.

At each hospital, one or more of the following (depending on local context) key informants were asked to complete their respective section of the capacity assessment tool by study team members to triangulate responses: surgeons, anesthetists, medical officers, professionals, technicians, and/or in-charge nurses from the casualty, theater, critical care, wards, laboratory, radiology, physiotherapy, procurement, accounts, and engineering departments. In keeping with other published assessments, resource availability was rated as: [21–24].

0—Absent but should be present;

1—Inadequate, available to less than half of those who need it;

2—Partially adequate, available to more than half, but not to most who need it; or

3—Adequate, present and readily available to almost everyone in need and used when needed.

Direct inspection of each of the resources was performed to corroborate ratings and ensure data validity.

Composite capacity score, surgical specialty availability, and hospital infrastructure

Ratings for the 25 essential surgical care resources and capabilities were summed to obtain a composite capacity score that ranged from 0 (no essential resource availability) to 75 (full and constant essential resource availability). At each facility, we also collected data on the availability of surgical specialties (e.g., in-hospital or on-call availability of specialty-trained surgeons with certification from the West African College of Surgeons in the fields of general surgery, obstetrics and gynecology, orthopedic surgery, urology, neurosurgery, plastic surgery, head and neck surgery, maxillofacial surgery, ophthalmology, pediatric, cardiovascular or thoracic surgery). Data on the surgical output of non-surgeons were not collected, as there is no formal general or special surgical training or certification for non-surgeons in Ghana analogous to surgical task-sharing programs in other countries [25–28]. First-level hospitals in Ghana consistently have between 50 and 100 beds and 1–3 operating rooms or procedure areas that are intermittently functional [14, 29]; however, referral and tertiary hospitals vary in bed capacity and the number of operating rooms. Therefore, we collected data on the number of hospital beds and number of functional operating rooms and/or procedure areas at referral and tertiary hospitals.

Surgical output

At each of the 37 hospitals, de-identified surgical logbook data from June 1, 2014, to May 31, 2015, from each operating room and/or procedure area were transcribed into Excel (Microsoft Corp., USA) by two study team members; a third member resolved data inconsistencies using the original logbook. The team members who collected the capacity

data were different from those who collected the output data; therefore, the team collecting the capacity data was blinded to the hospitals' outputs, and the team collecting the output data was blinded to the hospitals' capacity.

Our de facto definition of an 'operation' was: A procedure performed in an operating room or procedure area regardless of anesthesia type or type of provider performing the procedure. If more than one procedure was performed during a single 'operation,' only the primary procedure was counted. Operations were categorized as either 'essential' (i.e., most cost-effective, universally applicable, highest potential population impact) or 'advanced' (i.e., more expensive and/or complex, less potential population impact) using the guidelines from The World Bank DCP³ [3].

Data analysis

The composite surgical capacity score was described and found to be normally distributed (skewness 0.39, kurtosis 2.99, Shapiro–Wilk $p = 0.62$), as well as highly collinear with both the number of hospital beds and number of functional operation rooms and/or procedure areas (condition number 14.3 to 8.9 with the latter covariates excluded). Since surgical output was measured as counts, we sought to explore the relationship between surgical capacity and output using a Poisson model. However, the mean of the surgical output covariate was greater than its variance, which suggested significant over-dispersion; given over-dispersion and the observation that all of the sampled hospitals performed at least one operation, we explored the relationship between the surgical capacity score and surgical output using a zero-truncated negative binomial regression model [30, 31]. Bootstrap resampling was used to calculate standard errors and 95% uncertainty intervals (UIs). The initial model included a priori-defined terms for the capacity score and number of surgical specialties available, hospital beds, and functional operating rooms and/or procedure areas, which have been shown to correlate with surgical output [32]. After, we performed backward stepwise regression (covariate removed from the model if $p > 0.10$) given the relatively small number of covariates to determine whether omitting one or more of the additional explanatory covariates (i.e., covariates other than the composite capacity score) improved model fit. Using Akaike's information criterion, model fit was marginally better after omitting number of hospital beds and number of functional operating rooms and/or procedure areas from the model [33, 34]. Next, we compared the above models with and without omitting hospitals that had either a capacity score or output outlier with significant leverage and/or influence on the model; model fit was again improved with the omission of seven outlier hospitals. The final model was:

$$\text{Number of operations performed per year}_i = e^{\beta_0} \times e^{\beta_1(\text{composite surgical capacity score}_i)} \times e^{\beta_2(\text{number of surgical specialties available}_i)}$$

Ethical considerations

This study was approved by the ethical committees of the Kwame Nkrumah University of Science and Technology and the University of Washington. All participants gave informed consent, and all data were anonymously recorded.

Results

Hospital characteristics and essential surgical care capacity

Surgical capacity was assessed and surgical output data were collected from 37 hospitals: 26 first-level hospitals (70%), 8 referral hospitals (22%), and 3 tertiary hospitals (8%) (Table 2). All hospitals had medical officers who were able to perform some degree of surgical care; 5 hospitals had one surgical specialty available (14%); 11 hospitals had two specialties available (30%); 5 hospitals had three or four specialties available (14%); and 3 hospitals had five or more specialties available (8%) (Table 3).

Generally, there was greater availability of resources and capabilities at higher levels of care (i.e., first-level resource and capability availability < referral < tertiary hospitals) (Table 2). This was particularly the case for availability of blood transfusion, non-general surgical capabilities (e.g., orthopedic surgery, neurosurgery), and anesthesia machines. Several resources and capabilities were often available at all hospital levels, such as personal protective equipment, airway management, oxygen supply, and hemoglobin testing. However, several essential surgical care capabilities were not readily available even at tertiary centers (e.g., essential procedure capabilities for urology, major orthopedic, vascular, burn and plastic, and minor neurosurgical care).

The median composite surgical capacity score was 37 [interquartile range (IQR) 29–48; range 16–69] (Table 3); the score increased (i.e., greater capacity) and had a narrower distribution (i.e., more similar capacity) with increasing level of care: median surgical capacity score at first-level hospitals—34.5 (IQR 29–40; range 16–62); referral hospitals—38.5 (IQR 36–49; 16–56); tertiary hospitals—60.0 (IQR 53–69; 53–69).

Surgical output

There was marked variation in the surgical output across and within each hospital level. The median number of essential operations performed annually at first-level hospitals was 1581 operations (IQR 736–2167) compared to 1676 operations (IQR 1019–2643) at referral hospitals and 12,509 operations (IQR 3773–22,260) at tertiary hospitals. Further, higher hospital levels performed a greater proportion of operations not considered ‘essential’ by The World Bank; these operations represented 25% of operations performed at first-level hospitals, 36% at referral hospitals, and 43% at tertiary hospitals.

Relationship between capacity and output

The model did not demonstrate evidence for a predictive relationship between surgical capacity and essential surgical output (i.e., number of essential operations performed annually; $p = 0.90$) (Table 4; Fig. 1), advanced surgical output (i.e., number of advanced operations performed annually; $p = 0.60$), or total surgical output ($p = 0.59$). On the

contrary, there was evidence for a relationship between surgical specialty availability and essential, advanced, and total surgical output ($p = 0.05$, $p = 0.01$ and $p = 0.01$, respectively).

Discussion

This study aimed to explore the relationship between surgical capacity and output at hospitals in Ghana to improve our understanding and interpretation of capacity assessment results. Despite the use of a robust and widely accepted method for assessing surgical capacity at a large number of hospitals countrywide, we did not find a strong relationship between capacity and output. This finding provokes three important considerations: (1) existing surgical capacity assessment tools that rely predominantly on measurement of availability of infrastructure, physical and human resources, and surgical capabilities may not accurately reflect surgical output; (2) the availability of specialty-trained surgeons improves surgical output; and (3) additional factors that influence output may need to be incorporated into future assessments to improve their accuracy, including other demand-side factors (e.g., barriers to care), supply-side factors (e.g., policies, protocols, incentivization structures, compliance), and health administration and management factors (e.g., an enabling work environment, emotional infrastructure, financing schemes). By considering these additional factors potentially related to output, we may be able to improve the validity of surgical capacity assessments to more accurately reflect the ability to provide safe, effective, and efficient care, and facilitate the maximal use of existing and potential capacity through targeted health systems strengthening initiatives.

Demand-side factors that may reduce surgical output regardless of capacity include population awareness of surgical needs, access to care, and ease of healthcare navigation. A survey of patients with neglected surgical conditions from Ghana demonstrated that a complex amalgamation of cultural, financial, and structural barriers variably prevent many people from knowing when to seek care, seeking care, and receiving care beyond a simple lack of capable hospitals within a reasonable distance to their home [35]. Further, nearly 30% of Ghanaians are unable to reach a hospital capable of providing essential surgical care within 2 h, which results in variable presentations to care [18]. Further still, a study of population-level financial risk in Ghana demonstrated an inverse relationship between total household income and distance to surgical care, which is correlated with risk of both impoverishing and catastrophic health expenditure when care is required [36]. Surgical capacity is useless and becomes untethered to output when patients do not seek or are unable to access the resources available; therefore, future capacity assessments should consider including concurrent evaluation of the barriers to the care the patients face to facilitate the interpretation of surgical output across hospitals within a healthcare system and design of interventions to maximize resource allocation.

Supply-side factors other than essential resource availability that may reduce surgical output include the availability of additional: (1) structure elements (e.g., policies, protocols, incentivization structures); (2) process elements (e.g., service delivery, compliance with guidelines); and (3) health administration and management elements (e.g., enabling work environment, emotional infrastructure, financing schemes). Of course, a baseline level of context-appropriate physical and human resource availability is required to provide essential

surgical care; however, once these resources are established, other non-material resources may become particularly important for maximizing surgical safety, effectiveness, and efficiency. For example, addition of structural and process improvements to mature trauma systems (i.e., well-resourced systems) produces safer and more effective trauma surgical care [37]. Therefore, as physical and human resources become more available, the availability of certain ‘essential’ non-material resources and capabilities (e.g., policies, protocols, compliance with guidelines) should be agreed upon by stakeholders and measured in future capacity assessments [38]. Additionally, this study demonstrates the potential positive impact of specialty-trained surgeons on surgical output; efforts to grow this segment of the workforce should exist in parallel to other initiatives, such as task-sharing [3, 27, 28, 39].

Current assessments do not consider health administration and management elements, which may have a considerable effect on performance and output [40]. These include important, but difficult-to-measure, core competencies, such as strategic thinking and problem-solving; human resources management; financial management; operations management; performance management and accountability; governance and leadership; political analysis and dialog; and community and customer engagement. Several WHO health system assessment tools include proxies for these core competencies (e.g., Health System Performance Assessment, Service Availability and Readiness Assessment) [41]; however, these tools lack assessment of the emergency, trauma, and surgical care system useful for targeted development. While the causes of inefficiency (i.e., high capacity and low output) are certainly multifactorial, improved health administration and management may ensure that available capacity is used more resourcefully. Consequently, future capacity assessments should include proxies for health administration and management core competencies to potentially strengthen their validity.

Beyond the aforementioned additional elements, organizational factors may also play an important role in maximizing output. Nobel Laureate for Economics Amartya Sen theorized on the issue of individual and community utility (i.e., the effect of the use of available resources) and championed the ‘human capabilities approach’ [42, 43]. The human capabilities approach portends that it is not only the equipment, supplies, knowledge, and skills available that determines our ability to transform resources into valuable activities, but the environment within which we work and the faculty to make useful choices that maximize our utility. In this case, the human capabilities approach would stress that the health system ensure that surgical providers work in an ecosystem that enables and sustains safe and high-volume surgical care regardless of some resource limitations [44].

Although this report offers a useful examination of the relationship between surgical capacity and output, several limitations should be considered prior to drawing conclusions. First, the rating scheme used for the capacity assessment (0–3) was somewhat subjective. In an attempt to strengthen its validity, key informants from several departments within each hospital that interacted with the same resource (e.g., X-ray—emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, X-ray technicians, biomedical engineers) were surveyed about its availability to triangulate responses. Further, direct observation of each resource was performed. Second, two hospitals declined to participate in

the study; their resource availability and surgical output may be more or less correlated than was demonstrated at other hospitals; nonetheless, we have no reason to think that the results from those hospitals would be markedly different. Third, hospitals were not sampled at random, which may have introduced some degree of selection bias. However, our sampling strategy ensured that we included hospitals from each level of the healthcare system and that rected the variation in surgical capacity, geography (i.e., remoteness, differences in supply chain), and socioeconomic status of the catchment populations. By doing so, the data represent the reality of the use of surgical capacity as a proxy for output. Next, we only collected data on number of surgical specialties available; we did not collect data on the total number of specialists, or their “expertise” beyond their specialty training, including the types of procedures they are comfortable performing or have performed within the last year. While these data may have changed the model to some degree, hospitals that had a surgeon were limited not by number of surgical staff but operating rooms and anesthetists. Therefore, it is unlikely that the addition of these data would have markedly changed the relationship between capacity and output. Lastly, it is likely that institutional differences in recording of procedures led to some information bias; we attempted to minimize this by transcribing data from all possible areas in each hospital that performed procedures (e.g., operating rooms, procedure areas, and emergency units); the study teams did not find evidence for a relationship between capacity and potential differences in recording of procedures. Further, we excluded logbook data that was at high-risk of being discrepantly recorded across hospitals with variable records (i.e., dental and ophthalmologic procedures, which are often performed in a clinic and not recorded in a logbook). Despite the aforementioned limitations, the results from this report allow reasonable conclusions to be drawn about the potentially weak relationship between surgical capacity and output, as well as ways to better evaluate capacity and potentially improve the validity of future assessments.

Conclusions

Contrary to current understanding, surgical capacity assessments are too simplistic may not accurately predict surgical output. To improve the validity of future surgical capacity assessments and facilitate maximal use of available resources, other factors that inuence output should also be considered, including:

1. demand-side factors (barriers to care), such as population awareness of surgical need, cost and accessibility of care, ease of healthcare navigation;
2. supply-side factors, such as structure elements (e.g., policies, protocols, incentivization structures, and process elements), service delivery, and compliance with guidelines and protocols; and
3. health administration and management factors, such as an enabling work environment, emotional infrastructure, financing schemes.

Lastly, there is potentially much to be learned from hospitals with both low efficiency (i.e., high capacity and low output) and high efficiency (i.e., low capacity and high output) that could be used to improve the access to and availability of essential surgical care in low-resource settings.

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Fig. 1.

Relationship between surgical care capacity and essential surgical output at hospitals in Ghana. Capacity score—a composite score of 25 essential surgical care resources as outlined by the World Health Organization and The World Bank, the score ranges from 0 (no essential resource availability) to 75 (full and constant essential resource availability); surgical specialty coverage—in-hospital or on-call availability of general surgery-, obstetrics and gynecology-, orthopedics-, and/or urology-trained surgeon(s); operations performed per year—number of essential operations as defined by The World Bank Disease Control Priorities Project 3rd Edition performed from May 31 to June 1, 2014–2015, respectively; seven hospitals that had either a capacity score or output outlier with significant leverage and/or influence on the model were excluded

Table 1

Essential surgical resources and capabilities assessed at first-level, referral, and tertiary hospitals in Ghana

Resource or capability	Example elements
Personal protective and sterile attire equipment	Mask, gloves, impervious gowns, boots, hats, eye shields, of various sizes
Basic airway management	Nasal and oral airways, bag-valve-mask, Magill forceps, stethoscope
Suction device	Electric, foot-pump or otherwise with tubing and appropriate tip
Advanced management	Laryngoscope, lighted blades and endotracheal tubes of various sizes
Spine immobilization	Cervical collars or safely improvised device
Oxygen supply	Oxygen concentrator, tank or wall source; nasal cannulas and masks of various sizes
Tube thoracostomy	Various sizes, water seal device and instruments to insert
Pulse oximetry	Machine and probe
Mechanical ventilator	Machine and tubing
Blood transfusion	Safe blood collection, testing, storage and administration system
Hemoglobin	Manual or automated counting
X-ray	Stationary or portable X-ray
Ultrasound	Machine and probe(s)
Anesthesia machine	Machine and anesthetic gas
Minor surgical	Suture of laceration, incision and drainage, circumcision, herniorrhaphy, hydrocelectomy
Major surgical	Laparotomy for acute abdomen or injury, cholecystectomy, colostomy
Obstetric and gynecologic	Normal, instrumented and Cesarean birth; laparotomy for ectopic pregnancy, dilation, and curettage, tubal ligation, hysterectomy, inspection and/or cryotherapy for precancerous lesions
Urologic	Relief of urinary obstruction (urethral or suprapubic catheterization), vasectomy
Closed reduction	Closed reduction, splinting and casting
Skin or skeletal traction	Skin or skeletal traction, including chord and weights
Minor orthopedic	Drainage of septic arthritis, toileting of open fracture, debridement for osteomyelitis, non-operative club foot management
Major orthopedic	Fasciotomy, amputation
Vascular	Control, shunting and repair of major vascular injury
Burn and plastic	Skin grafting, escharotomy
Minor neurosurgical	Burr hole placement; management of open, depressed skull fracture, shunt for hydrocephalus

Table 2

Essential surgical resources and capabilities available at first-level, referral, and tertiary hospitals in Ghana

	Median item availability rating (range)		
	First-level (26)	Referral (8)	Tertiary (3)
<i>Airway and PPE</i>			
Personal protective equipment	2 (1–3)	3 (2–3)	3 (2–3)
Basic management	2 (0–3)	2 (0–3)	2 (2–3)
Suction device	2 (0–3)	2 (0–3)	2 (2–3)
Advanced management	3 (0–3)	3 (0–3)	3 3
Spine immobilization	0 (0–3)	0 (0–1)	1 (0–3)
<i>Breathing</i>			
Oxygen supply	3 (1–3)	3 (2–3)	3 (2–3)
Tube thoracostomy	0 (0–3)	0 (0–2)	3 (2–3)
Pulse oximetry	3 (0–3)	2 (2–3)	3 (2–3)
Mechanical ventilator	2 (0–2)	1 (0–3)	3 (1–3)
<i>Circulation and laboratory</i>			
Blood transfusion	2 (1–3)	2 (1–3)	2 (2–3)
Hemoglobin	3 (1–3)	3 (2–3)	3 3
<i>Imaging</i>			
X-ray	2 (0–3)	2 (0–3)	2 (2–3)
Ultrasound	0 (0–3)	0 (0–2)	3 (0–3)
<i>Surgical capabilities</i>			
Anesthesia machine	2 (0–2)	2 (1–3)	3 (2–3)
Minor general surgical	3 (0–3)	3 (0–3)	3 (2–3)
Major general surgical	1 (0–3)	3 (0–3)	3 (2–3)
Obstetric and gynecologic	3 (0–3)	3 (1–3)	3 3
Urologic	1 (0–3)	2 (1–3)	3 (1–3)
Closed reduction	2 (0–3)	3 (0–3)	3 3
Skin or skeletal traction	0 (0–3)	2 (0–3)	3 (2–3)
Minor orthopedic	0 (0–3)	0 (0–3)	3 3
Major orthopedic	0 (0–3)	0 (0–1)	2 (1–3)
Vascular	0 (0–2)	0 (0–2)	1 (0–3)
Burn and plastic	0 (0–3)	0 (0–2)	2 (1–3)
Minor neurosurgical	0 (0–1)	0 0	1 (0–3)

PPE personal protective equipment; rating scheme: 0—absent; 1— inadequate, available to less than half of those who need it; 2— partially adequate, available to more than half, but not to most who need it; 3—adequate, present and readily available to almost everyone in need and used when needed

Table 3
Capacity, surgical specialty availability, and surgical output from first-level, referral, and tertiary hospitals in Ghana

	Capacity score	Surgical specialty availability ^a	Number of essential operations	Number of advanced operations	Total number of operations
First-level (median)	34.5	1	1480	460	2050
Hospital 1	16	0	708	21	728
Hospital 2	18	0	736	80	816
Hospital 3	20	2	1726	439	2165
Hospital 4	22	0	1188	294	1483
Hospital 5	23	1	1222	654	1875
Hospital 6	25	0	1100	933	2033
Hospital 7	29	0	3661	483	4144
Hospital 8	29	2	1932	455	2387
Hospital 9	29	0	1873	351	2224
Hospital 10	32	0	426	39	465
Hospital 11	33	0	390	483	873
Hospital 12	33	2	2260	568	2829
Hospital 13	34	1	1589	178	1767
Hospital 14	35	2	2154	493	2648
Hospital 15	37	0	803	23	827
Hospital 16	38	0	1925	142	2067
Hospital 17	38	0	1578	1413	2991
Hospital 18	40	2	1240	54	1294
Hospital 19	40	2	88	34	121
Hospital 20	40	0	320	67	387
Hospital 21	43	1	3172	561	3733
Hospital 22	48	2	3712	940	4653
Hospital 23	49	1	8220	2441	10,661
Hospital 24	50	3	1852	3309	5161
Hospital 25	51	2	150	465	615
Hospital 26	62	2	1382	883	2266
Referral (median)	38.5	3	1545	658	2497

	Capacity score	Surgical specialty availability ^a	Number of essential operations	Number of advanced operations	Total number of operations
Hospital 1	16	1	411	40	451
Hospital 2	36	0	1066	259	1325
Hospital 3	36	2	3750	730	4480
Hospital 4	37	2	1408	601	2009
Hospital 5	40	3	2361	715	3076
Hospital 6	47	4	1681	1303	2984
Hospital 7	51	4	2542	773	3316
Hospital 8	56	4	902	586	1487
Tertiary (median)	60	7	11,757	3839	15,596
Hospital 1	53	6	3769	1606	5375
Hospital 2	60	10	21,256	17,182	38,438
Hospital 3	69	7	11,757	3839	15,596
All hospitals (median)	37	2	1589	493	2165

Capacity score—a composite score of 25 essential surgical care resources as outlined by the World Health Organization and The World Bank, the score ranges from 0 (no essential resource availability) to 75 (full and constant essential resource availability)

^aSurgical specialty availability—in-hospital or on-call availability of general surgery-, obstetrics and gynecology-, orthopedics-, and/or urology-trained surgeon(s); number of operations performed from May 31st to June 1st 2014–2015, respectively; operations were categorized as either ‘essential’ (i.e., most cost-effective, universally applicable, highest potential population impact) or ‘advanced’ (i.e., more expensive and/or complex, less potential population impact) using the guidelines from The World Bank Disease Control Priorities Project 3rd Edition

Table 4

Relationship between surgical capacity and surgical output at hospitals in Ghana

	Coefficient	Lower UI	Upper UI	p value
Essential surgical output				
Composite surgical capacity score	0.002	- 0.029	0.032	0.90
Number of surgical specialties available	0.150	- 0.002	0.302	0.05
Advanced surgical output				
Composite surgical capacity score	0.009	- 0.025	0.043	0.60
Number of surgical specialties available	0.330	0.088	0.572	0.01
Total surgical output				
Composite surgical capacity score	0.005	- 0.014	0.024	0.59
Number of surgical specialties available	0.190	0.085	0.295	0.01

Surgical output defined as number of operations performed per year; operations were categorized as either 'essential' (i.e., most cost-effective, universally applicable, highest potential population impact) or 'advanced' (i.e., more expensive and/or complex, less potential population impact) using the guidelines from The World Bank Disease Control Priorities Project 3rd Edition; composite surgical capacity score—a composite score of 25 essential surgical care resources as outlined by the World Health Organization and The World Bank, the score ranges from 0 (no essential resource availability) to 75 (full and constant essential resource availability); surgical specialty availability—in-hospital or on-call availability of general surgery-, obstetrics and gynecology-, orthopedics-, and/or urology-trained surgeon(s)