The Kenya Surgical Capacity Study: An Audit of Surgical Equipment/Infrastructure in Level 4 Public Hospitals

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Abstract

Background: Access to surgical equipment is critical to providing safe and equitable operative care. This is the first nationwide study to provide data on the availability of surgical equipment in Kenya. **Methods:** This cross-sectional study collected data from May to July 2018 on the availability of non-pharmaceutical equipment, patient care, intra-operative, and anesthesia supplies in level 4 hospitals. Information regarding infrastructure such as the number of functional operating rooms, sterilization capacity, and sources of water and electricity was also collected. **Results:** The availability of intra-operative and anesthesia equipment was 44.5% and 47%, respectively. Nearly 60% of facilities had general patient care supplies. Over 80% of the facilities had running water in maternity wards (83.1%). Sterilization equipment was present in about half of the facilities (range: 42.6–68.3%). Additionally, 79.1% had a generator as a backup source of electricity. Only 35% of facilities always had an X-ray on-site, and 52.6% of the facilities obtained blood from the national or a regional center. **Conclusion:** This study provides data on the availability of surgical equipment and infrastructure in level 4 hospitals in Kenya. Availability of radiology services and blood supply was lower than that in other sub-Saharan African countries, highlighting the need for improved surgical care resources in these community-based facilities.

Keywords: Kenya, National surgical capacity, Surgical equipment, Surgical infrastructure

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Introduction

Surgical capacity is a pillar in providing quality healthcare and in the establishment of health equity. Access to safe and appropriate surgical care can lower the mortality and morbidity for many easily treatable diseases. Yet, low- and middle-income countries (LMICs) continue to be disproportionately affected in accessibility to this key aspect of healthcare, with 9 out of 10 people without access to basic surgical care (1). Beyond the devastatingly large number of deaths caused by the lack of access to surgical care, the economic impact on LMICs with inadequate surgical capacity is striking. LMICs are expected to lose up to 12.3 trillion USD in productivity by 2030 if surgical capacity is not bolstered to the requisite levels (1).

While most of the literature focuses on scaling up the surgical workforce, ensuring the quality of the infrastructure and surgical equipment is another important foundation of a safe and accessible healthcare system (2). One of the contributing factors to the high rates of delayed or cancelled procedures in LMICs is poor infrastructure and equipment shortages (3, 4). Furthermore, the equipment accessible in many of these countries is largely donated, which presents problems in regard to maintenance and servicing the equipment (5, 6). Previous studies from Kenya report that most of the broken medical equipment is not repaired swiftly (7). Additionally, with consideration to the significantly high surgical site infection rates in LMICs, it is critical to assess the capabilities of facilities to perform safe surgeries and sterile processing (8). Without adequate infrastructure and equipment, safe surgical and anesthetic care simply cannot be achieved.

The aim of this study was to evaluate and report on the accessibility of surgical equipment nationwide. Collecting and reporting these data will aid the Kenya Ministry of Health (MoH) and stakeholders in the development of future polices for establishing equitable surgical care nationally.

Materials and Methods

Study design

This study collected qualitative, quantitative, and direct observational data in all 249 level 4 government (public) health facilities in Kenya. All level 4 hospitals listed in the official Kenya MoH roster were included. A level 4 health facility is the principal primary referral hospital for communities, especially for rural communities. It offers services that compliment primary healthcare to allow for the delivery of more comprehensive care, including medical and surgical specialties and diagnostic laboratory facilities. A total of seven healthcare facilities were excluded. Two facilities originally listed by the MoH as level 4 hospitals were excluded as these two facilities no longer met the criteria for level 4 hospitals when this study was initiated. Other exclusion reasons were security issues or inaccessibility.

Study tool

In order to establish a baseline and track the performance of health service provision across the country, the development of a simple yet effective measurement tool was required, and thus the Kenya Hospital Assessment Tool (K-HAT) was developed (9). The K-HAT, whose development is reported in another publication (9), was adapted from the World Health Organization's (WHO) Service Availability and Readiness Assessment tool and the Situational Analysis Tool. We used the K-HAT to collect data from all level 4 hospitals in Kenya. The K-HAT collected quantitative data such as surgical workforce, surgical volume, and surgical equipment (9).

Research personnel and training

Research assistants (RAs) were employed for this study from the Kenya Progressive Nurses Association, whose membership spans across all 47 counties in Kenya. The RAs underwent a 2-day training workshop in Nairobi to familiarize them with the survey tool and train them in interview techniques. An online text-based group was created to facilitate any subsequent issues that may arise, as well as to enhance further communication and coordination among the RAs and the study administrators.

Data collection

From May 2018 to July 2018, 25 RAs conducted site visits to level 4 hospitals across Kenya. Data collection

was carried out using the K-HAT (9). Data were collected and recorded electronically, using a researcher-designed encrypted database—Open Data Kit (ODK). The study tool was programmed into the ODK format and uploaded on an ODK collect application for data collection. The tablets were configured to the Africa Medical and Research Foundation (AMREF) Health Server to allow for direct transfer of data once they were collected. On-site inspection, in-person interviews, and spot logbook assessments were also conducted.

Surgical equipment and infrastructure definition

Availability of general patient care, intra-operative, anesthesia, and non-pharmaceutical equipment and supplies was recorded for each hospital. Non-pharmaceutical supplies were divided into two categories. Category 1 included supplies that are considered essential to the performance of day-to-day surgery. Category 2 included supplies that can be replaced by alternatives. Detailed information for the supplies in each category can be found in Supplemental Figure 1. Information regarding infrastructure and resources such as the number of functional operating rooms, sterilization capacity, main sources of water, availability of running water in the operating room and maternity ward, main sources of electricity and backup sources, blood bank capacity, and pre-transfusion screening capacity was collected. Functional surgical theaters were defined as having an operating table, ventilator, operating room light, and oxygen cylinder. A major surgical theater is an operating theater where surgeries performed under general or spinal anesthesia for a duration of at least 1 hour can occur, while minor surgical theaters perform surgeries conducted under local anesthesia.

Table 1. Hospital facility characteristics and resources at level 4 hospitals in Kenya

	Facilities performing the procedure, N=249 (n, %)			
Laboratory services	**Yes, on-site (always available), n (%)**	**Yes, on-site (sometimes available), n (%)**	**Yes, offsite, n (%)**	**Do not conduct the test, n (%)**
Tests				
Hemoglobin test	204 (82)	26 (10)	9 (4)	10 (4)
Complete blood count	148 (59)	35 (14)	12 (5)	54 (22)
Blood sugar tests	218 (88)	19 (8)	6 (2)	6 (2)
Chest X-ray	86 (35)	16 (6)	12 (5)	135 (54)
ECG	14 (6)	7 (3)	6 (2)	222 (89)
Serum creatinine testing	90 (36)	33 (13)	13 (5)	113 (46)
Other renal function testing (such as urea nitrogen)	84 (34)	33 (13)	12 (5)	120 (48)
Blood group serology tests				
ABO blood grouping test	209 (84)	15 (6)	12 (5)	13 (5)
Rhesus blood grouping test	212 (85)	16 (6)	11 (4)	10 (4)
Cross-match by direct agglutination	131 (52)	14 (6)	7 (3)	97 (39)
Cross-match by indirect antiglobulin testing or other tests with equivalent sensitivity	102 (41)	20 (8)	8 (3)	119 (48)

ECG, electrocardiogram.

The main source of water was denoted as water availability at all times. Laboratory services available (tests and blood group serology tests) were also recorded.

Table 2. Infrastructure and surgical capacity resources at level 4 facilities in Kenya

Infrastructure and resources	Availability at level 4 facilities, N=249, n (%)		Availability at level 4 facilities, N=249, n (%)
Operating room/number of facilities with functional theaters[1]		**Secondary or backup source of electricity**	
Major	122 (49)	Generator (fuel or battery-operated generator)	197 (79.1)
Minor	135 (54)	Solar system	19 (7.6)
Sterilization unit		No secondary source	26 (10.4)
Autoclave large	170 (68.3)	Other (chargeable lamp, phone light/gas lanterns)	3 (1.2)
Instrument racks	127 (51)	**Blood bank**	
Sterile instrument shelves	149 (59.8)	Stock-outs in blood during the past 3 months	160 (64.26)
All surgical sets	106 (42.6)	Facilities obtaining blood from a national or regional blood center	131 (52.61)
Preparation tables	138 (55.4)	Facilities obtaining blood from sources other than the national or regional blood center	77 (30.92)
Instrument washing units	127 (51)	Facilities collecting blood from family replacement donors	70 (28.11)
Instrument cupboard	130 (52.2)	Tests used to screen donors and blood at the facilities (rapid diagnostic tests, ELISA)	178 (71.49), 71 (28.51)
Non-pharmaceutical cupboard	136 (54.6)	**Facility screening for any of the following infectious diseases before transfusion**	
Linen cupboard	112 (45)	**HIV**	
Main source of water[2]		Always	182 (73.09)
Piped in facility	158 (63.45)	Sometimes	1 (0.40)
Piped onto facility grounds	50 (20.1)	Never	50 (20.08)
Public tap/standpipe	47 (18.9)	Unsure	16 (6.43)
Tube well/borehole	21 (8.4)	**Syphilis**	
Protected dug well	1 (0.4)	Always	181 (72.69)
Unprotected dug well	86 (34.5)	Sometimes	1 (0.40)
Rainwater collection	1 (0.4)	Never	51 (20.48)
Bottled water	3 (1.2)	Unsure	16 (6.43)
Cart with small tank	6 (2.4)	**Hepatitis B**	
Surface water	4 (17.7)	Always	181 (72.69)
Others (from river)	3 (1.2)	Sometimes	1 (0.40)
		Never	51 (20.48)
Availability of running water in:		Unsure	16 (6.43)
Theater	121 (48.59)	**Hepatitis C**	
Maternity	207 (83.13)	Always	168 (67.47)
Facility's main source of electricity		Sometimes	6 (2.41)
Central supply of electricity (national grid)	233 (93.57)	Rarely	6 (2.41)
Generator (fuel or battery-operated generator)	12 (4.82)	Never	53 (21.29)
Solar system	4 (1.61)	Unsure	16 (6.43)
		Facilities having guidelines on the appropriate use of blood and safe transfusion practices	159 (63.86)

[1]Refers to the section under theater (table, ventilator, OR light, O_2 cylinder). (Please note: O_2 saturation monitor is missing from the list.)

[2]Indicates availability at all times.

ELISA, enzyme-linked immunosorbent assay.

Table 3. Availability of hospital supplies and equipment at level 4 facilities in Kenya

County	County population	No. of level 4 facilities	Equipment and supplies[1]				
			General patient care supplies	Intra-operative equipment and supplies	Anesthesia equipment and supplies	Non-pharmaceutical	
			Availability (%)	Availability (%)	Availability (%)	Category 1, availability (%)	Category 2, availability (%)
Baringo	666,763	3	70.2	53.8	56.7	74.6	57.9
Bomet	875,689	3	51.8	57.0	66.7	49.1	38.6
Bungoma	1,670,570	9	53.5	32.3	33.3	61.0	49.7
Busia	893,681	5	46.8	63.9	68.0	69.2	56.8
Elgeyo-Marakwet	454,480	6	71.1	15.1	15.0	61.6	67.5
Embu	608,599	4	58.6	34.7	37.5	49.3	44.7
Garissa	841,353	6	50.0	41.4	50.0	59.2	48.3
Homa Bay	1,131,950	12	60.1	39.0	44.2	53.5	45.6
Isiolo	268,002	3	71.1	63.4	66.7	60.5	50.9
Kajiado	1,117,840	3	69.3	53.8	53.3	64.0	56.1
Kakamega	1,867,579	11	85.4	61.6	59.1	52.3	51.2
Kericho	901,777	7	51.5	43.8	48.6	53.9	47.4
Kiambu	2,417,735	5	57.4	47.7	56.0	52.9	42.1
Kilifi	1,453,787	5	79.5	85.1	88.0	69.2	52.6
Kirinyaga	610,411	4	65.1	58.1	62.5	64.8	53.9
Kisii	1,266,860	13	59.7	20.1	23.8	54.7	42.9
Kisumu	1,155,574	7	38.4	24.9	27.1	42.3	45.9
Kitui	1,136,187	10	61.6	41.6	40.0	79.5	62.6
Kwale	866,820	3	40.4	72.0	73.3	73.3	61.4
Laikipia	518,560	4	63.8	42.7	42.5	62.2	51.3
Lamu	143,920	2	50.0	72.6	75.0	91.5	55.3
Machakos	1,421,932	4	81.6	46.8	50.0	92.4	75.0
Makueni	987,653	8	78.0	80.6	82.5	86.0	68.4
Mandera	867,457	4	58.6	37.1	42.5	67.7	47.4
Marsabit	459,785	2	81.6	85.5	95.0	82.2	63.2
Meru	1,545,714	11	47.1	23.8	24.5	58.1	51.7
Migori	1,116,436	11	55.3	44.0	43.6	46.9	40.2
Mombasa	1,208,333	3	79.0	83.9	80.0	80.3	61.4
Murang'a	1,056,640	7	43.2	36.9	35.7	58.6	60.2
Nairobi	4,397,073	1	63.2	83.9	90.0	90.8	73.7
Nakuru	2,162,202	7	78.6	59.0	64.3	72.7	57.1
Nandi	885,711	5	64.2	42.6	44.0	74.7	60.0
Narok	1,157,873	4	64.5	52.4	55.0	61.8	56.6
Nyamira	605,576	9	57.3	5.4	7.8	58.9	38.0
Nyandarua	638,289	2	92.1	90.3	95.0	73.7	60.5
Nyeri	759,164	3	86.0	76.3	83.3	75.0	70.2
Samburu	310,327	1	71.1	74.2	80.0	82.9	57.9
Siaya	993,183	6	33.3	44.1	48.3	44.1	46.5
Taita-Taveta	340,671	4	30.9	46.8	50.0	66.8	55.3
Tana River	315,943	3	39.5	57.0	60.0	64.9	63.2
Tharaka-Nithi	393,177	4	59.2	42.7	42.5	72.7	59.2
Trans-Nzoia	990,341	6	73.7	31.7	30.0	68.4	61.4
Turkana	926,976	3	50.0	28.0	26.7	54.8	38.6
Uasin Gishu	1,163,186	5	38.4	38.7	38.0	45.0	51.6
Vihiga	590,013	3	91.2	66.7	70.0	50.9	54.4
Wajir	781,263	7	39.1	36.4	47.1	51.3	38.4
West Pokot	621,241	1	71.1	0.00	0.0	43.4	47.4
Overall		**249**	**59.8**	**44.5**	**47.0**	**61.7**	**52.25**

[1]Only equipment and supplies that are available and working.

Statistical analysis

Descriptive analysis was performed using Microsoft Excel or Stata version 16.0 (StataCorp, College Station, TX, USA).

Ethical considerations

Ethical approval for the study was given by the AMREF Health Africa Ethics and Research Committee (ID# P451).

Results

Out of 254 level 4 hospitals in Kenya, 249 were available for data collection.

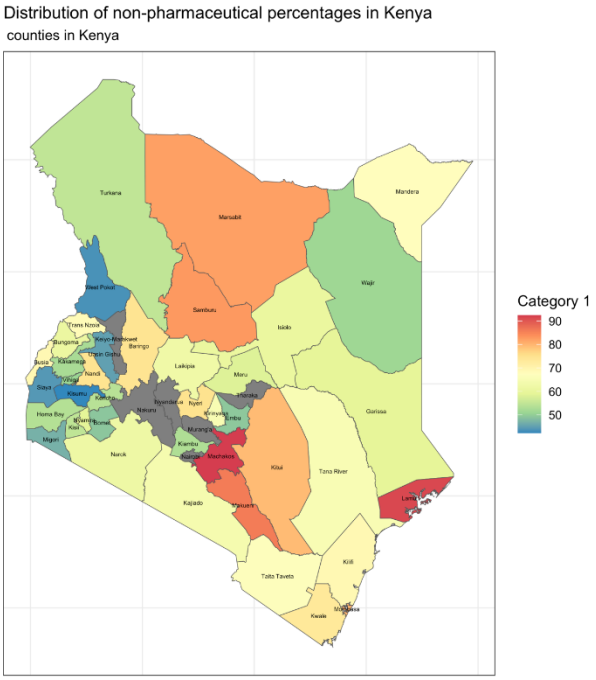

Figure 1. Distribution of category 1 non-pharmaceutical supplies across Kenya.

The capacity of laboratory services is presented in Table 1. In summary, the majority of facilities always had an on-site hemoglobin test (82%), blood sugar tests (88%), ABO blood grouping tests (84%), and Rhesus blood grouping tests available (85%) (Table 1). However, only 59% of the facilities had the ability to perform a complete blood count test. In addition, 89% of the hospitals do not conduct an electrocardiogram, 54% do not perform a chest X-ray, and about half of the facilities do not perform renal function testing (48%) or serum creatinine testing (46%) (Table 1).

In terms of infrastructure, about half of the facilities had a functional theater for major operations and a functional theater for minor operations (49% and 54%, respectively) (Table 2). More than three-fourths of the facilities have running water available in the maternity wards (83.1%) (Table 2). Availability of running water in the operating room was reported in 48.6% of the hospitals, and the main source of water for 63.5% of the facilities was piped into the facility (Table 2). In terms of sterilization capacity, 68.3% of facilities had a large autoclave unit in the hospital (Table 2). Additionally, nearly all the hospitals had a central supply of electricity from the national grid (93.6%) and 79.1% of facilities had a generator available as a backup source of electricity (Table 2).

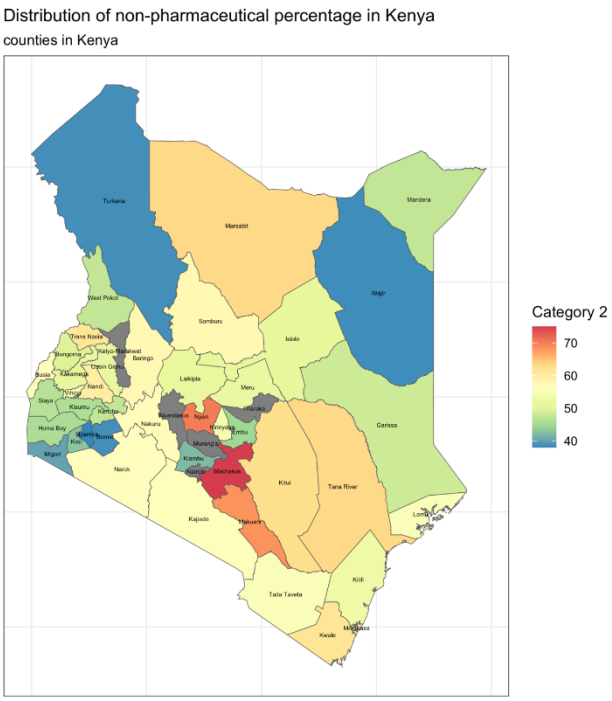

Figure 2. Distribution of category 2 non-pharmaceutical supplies across Kenya.

About half of the hospitals obtain blood from the national or a regional blood center (52.6%) (Table 2). Stock-outs in blood supply in the past 3 months were reported in 64.6% of the hospitals (Table 2). The majority of hospitals (71.5%) had a rapid diagnostic test

available to screen donors and blood, while 28.5% of facilities had an enzyme-linked immunosorbent assay (ELISA) available (Table 2). Nearly three-fourths of the facilities always had HIV, syphilis, hepatitis B, or hepatitis C screening available before blood transfusion (73.1%, 72.7%, 72.7%, 67.5%, respectively) (Table 2). Lastly, 63.9% of hospitals had guidelines on the appropriate use of blood and safe transfusion practices (Table 2).

Overall, the availability of intra-operative and anesthesia equipment and supplies was 44.5% and 47%, respectively. General patient care supplies were available in 59.8% of the facilities. The availability of non-pharmaceutical supplies for category 1 and category 2 was 61.7% and 52.3%, respectively (Table 3). Graphical distribution of categories 1 and 2 is visualized in Figures 1 and 2.

Discussion

This study provides information on the availability of necessary surgical equipment and infrastructure in level 4 hospitals in Kenya from 2018. Overall, the availability of surgical supplies, both intra-operative and anesthesia equipment, was found in less than half of the hospitals sampled (44.5% and 47%, respectively). Non-pharmaceutical supplies labeled as category 1 and category 2 were found in less than two-thirds of the level 4 facilities (61.7% and 52.25%, respectively). These results demonstrate that to scale up surgical capacity in Kenya, stakeholders should also aim to provide reliable surgical equipment to reach the goal of safe surgery for all.

Compared to other studies that investigated the capacity of hospitals in other African countries, our results fall below the reported margins of access in the context of radiology services and blood bank capacity. It has been reported that only 41% and 63% of hospitals in Nigeria and Botswana, respectively, have access to a radiograph machine, and over 50% of hospitals worldwide are without access to any radiology services (10-12). We found that only 35% of facilities across all level 4 hospitals in Kenya always had an X-ray available on-site and 54% do not provide this service. As it has been cited that 72% of trauma patients in Kenya require an X-ray, this data provides valuable information on which areas of care need the most attention (13, 14).

Risk of transfusion-transmissible infections (TTIs) are significantly higher in facilities that do not have adequate testing capabilities. In addition to the high rate of stock-outs of blood supply in the Kenyan facilities surveyed (64.3%), only 28% of the facilities had access to an ELISA test to detect TTIs. The majority of the facilities (71.5%) had access to a rapid diagnostic test. Although one might argue that any access to testing for TTIs is a step toward equitable healthcare, studies have found that the sensitivity of a rapid test for blood TTIs is much lower than that of an ELISA test (15). The lower cost and greater feasibility of a rapid test makes it more preferred by blood banks. However, widespread use of an unreliable testing mechanism is concerning as TTIs remain a major health problem in LMICs.

Barriers to adequate surgical equipment can also be associated with problems associated with donated equipment. The WHO reports that 89% of the equipment in low-resource facilities is donated (16). However, much of the donated equipment is tailored to the high-resource countries from which they originate. This leaves LMICs with donated equipment that does not match the voltage or frequency of the electricity network of their country, leading to overheating of the supplies and a shortened lifespan (17). Underinvestment in equipment maintenance and manufacturing companies often neglectful in providing the necessary repairs leaves about 40% of healthcare equipment out of service in low-resource countries (18, 19). Furthermore, inaccurate packaging/labeling, poor compliance with WHO's donation guidelines, inadequate stock keeping, cultural barriers, and lack of education and training substantially contribute to the barriers in donated medical equipment (19-23). The mass amount of unusable equipment in facilities that desperately need them is a significant contributor to the inequity in surgical and anesthetic care seen in low-resource countries (24).

Despite this study being the first of its kind to provide real-world data on the availability of necessary surgical tools and equipment, there are some limitations worth noting. First, the data presented in this paper was

collected in 2018. Due to the COVID-19 pandemic and challenges with research personnel, there was a delay in the publication of this valuable data. Therefore, the lack of availability in the resources measured may have grown since then. Additionally, non-level 4 facilities and private hospitals were not included in this study. The goal of the Kenya MoH and related stakeholders was to target facilities that provide the most comprehensive surgical services at the community level. Thus, evaluating the surgical capacity of level 4 hospitals was seen as the key factor in establishing a National Surgical, Obstetric, Anesthetic Plan (NSOAP). Lastly, the supplies evaluated in this study were only equipment that has been deemed necessary for general lifesaving procedures. Therefore, equipment that is required for more specialized surgical procedures was not assessed. The limitations mentioned clearly make it difficult to generalize our study findings outside level 4 public hospitals. Nevertheless, these granular data represent all 249 level 4 hospitals in Kenya comprehensively, creating a baseline against which future studies can be measured. Similar studies focusing on referral hospitals (level 5 and 6) would provide additional invaluable data to guide policy formulation.

This paper concludes the report of the assessment of surgical capacity throughout Kenya. We have found that accessibility to surgical workforce, the volume of surgical procedures, and availability of surgical equipment can all be improved. In order to improve the healthcare gap in Kenya, all three facets must be addressed concurrently. Attention to one will not be sufficient to reduce the mortality rate, but instead could increase the operational strain on the others, furthering health inequity in the country (25). Although improvement to one facet can improve outcomes, we suggest that investment in surgical capacity should be viewed as multifaceted.

A nationwide health initiative should always be tailored to the individual country's needs. Therefore, we hope that this series of reports can provide the Kenya MoH and other stakeholders in the country adequate data to begin the process of scaling up surgical capacity in Kenya and to develop a plan to provide equitable and safe surgical and anesthetic care to every patient in Kenya.

Conclusion

In this assessment of surgical accessibility in Kenya, we present data on the state of the infrastructure and availability of surgical equipment at community-level hospitals across the country. We found that generally, the availability of surgical supplies and non-pharmaceutical supplies was found at half of the level 4 hospitals. Improving the availability of surgical equipment and infrastructure should be strongly considered in order to meet the needs of community-based facilities nationwide and develop a comprehensive NSOAP.

Author contributions

Sara Chaker and Jaymie Ang Henry are co-first authors. SC equally contributed to formal analysis and in writing, reviewing & editing of the original draft. JAH and PN equally contributed to conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision and in reviewing & editing of the original draft. YH equally contributed to formal analysis and reviewing & editing of the original draft. MS and ES equally contributed to reviewing & editing of the original draft. SKM equally contributed to conceptualization, investigation, methodology and supervision. EW equally contributed to methodology, project administration, resources and supervision. PM equally contributed to conceptualization, methodology, project administration, resources and supervision. PJ equally contributed to conceptualization, investigation, methodology, project administration, resources, supervision and validation. KL equally contributed to visualization. PN equally contributed to validation and visualization.

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