World J Surg (2021) 45:1306–1315
https://doi.org/10.1007/s00268-020-05925-0

Assessment of Surgical Care Provided in National Health Services Hospitals in Mozambique: The Importance of Subnational Metrics in Global Surgery

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Accepted: 13 December 2020 / Published online: 31 January 2021

Abstract

Introduction Surgery plays a critical role in sustainable healthcare systems. Validated metrics exist to guide implementation of surgical services, but low-income countries (LIC) struggle to report recommended metrics and this poses a critical barrier to addressing unmet need. We present a comprehensive national sample of surgical encounters from a LIC by assessing the National Health Services of Mozambique.

Material and methods A prospective cohort of all surgical encounters from Mozambique's National Health Service was gathered for all provinces between July and December 2015. Primary outcomes were timely access, provider densities for surgery, anesthesiology, and obstetrics (SAO) per 100,000 population, annualized surgical procedure volume per 100,000, and postoperative mortality (POMR). Secondary outcomes include operating room density and efficiency.

Results Fifty-four hospitals had surgical capacity in 11 provinces with 47,189 surgeries. 44.9% of Mozambique's population lives in Districts without access to surgical services. National SAO density was 1.2/100,000, ranging from 0.4/100,000 in Manica Province to 9.8/100,000 in Maputo City. Annualized national surgical case volume was 367 procedures/100,000 population, ranging from 180/100,000 in Zambezia Province to 1,897/100,000 in Maputo City. National POMR was 0.74% and ranged from 0.23% in Maputo Province to 1.78% in Niassa Province.

Discussion Surgical delivery in Mozambique falls short of international targets. Subnational deficiencies and variations between provinces pose targets for quality improvement in advancing national surgical plans. This serves as a template for LICs to follow in gathering surgical metrics for the WHO and the World Bank and offers short- and long-term targets for surgery as a component of health systems strengthening.

Introduction

Surgery plays a critical role in sustainable healthcare systems but only recently gained visibility in global health policy [1–4]. In 2015, the Lancet Commission on Global

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Surgery (LCoGS) estimated that 5 billion people lack timely access to surgical care and that a minimum of 140 million surgical procedures are required annually to address the current unmet need worldwide [5, 6]. Failure to address this critical public health issue will lead to global losses in productivity cumulatively estimated at $12.3 trillion USD by 2030 [7].To expedite the realization of gains in health and economic development, the World Health Organization (WHO) unanimously passed Resolution 68/15 in 2015, calling for meaningful and reliable measures on access to surgical care [8].

Commensurately, the WHO and World Bank (WB) endorsed a suite of indicators for monitoring and evaluation of surgical services [9, 9]. However, large deficiencies exist in the reporting these metrics [10]. Of all United Nations member states, 80% report surgical–anesthesia and obstetric provider densities, 37% report volume of surgery per 100,000 population, 10% report timely access to surgery, 5% report postoperative mortality rate, and no countries report standardized values for catastrophic and impoverishing expenditures [10]. Despite early successes formulating National Surgical, Obstetric, and Anesthesia Plans (NSOAPs), most of these aspirational documents do not build on a foundation of data. Low-income countries (LICs) especially struggle to report recommended metrics and this poses a critical barrier to addressing unmet need where it is needed the most [11, 12].

We present a comprehensive national sample of surgical encounters from a LIC by assessing the National Health Services of Mozambique (NHSM). Mozambique is a LIC situated in the southeast of Africa with a population of 25 million [13–15]. Currently, there are fewer than 35 Mozambican general surgeons (0.14/100,000 inhabitants) and the country relies heavily on nonphysician technicians and expatriate surgeons from Cuba, China, and North Korea [16–18]. As a first step in developing a national surgical plan for Mozambique, we assessed the NHSM hospitals for all provinces using the surgical indicators developed by the LCoGS and adopted by the WB and WHO [2, 9, 9].

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Methods

Overview/setting

A prospective cohort of all consecutive surgical encounters from NHSM was gathered from July to December of 2015. The NHSM distributes healthcare facilities comprehensively over the country's 128 geographic districts, which are organized into 11 Provinces, namely Niassa, Manica, Tete, Inhambane, Gaza, Nampula, Zambezia, Cabo Delgado, Sofala, Maputo Province, and Maputo City [19].(Fig. 1) Hospitals were selected for inclusion based on the presence of an operating room (OR) and the appropriate staffing to carry out basic surgical procedures such as fractures, trauma, exploratory laparotomy, and cesarean section. Surgical providers, health managers, and administrative personnel collected data from daily reports using a predefined data collecting form. All data were sent at monthly intervals to the research team in hard copies or electronically over secure networks. In order to ensure accuracy and reliability, the research team conducted periodic site visits to all health units in the study. Data reports were compared to data sources, and individual patient charts were consulted to confirm deaths and time from operation to death. Data entry was performed in Excel on a secure computer in the capital city, Maputo. The study protocol was granted ethical approval by the Mozambique National Bioethics Committee.

Data definitions

Surgical data were collected according to definitions described in the LCoGS [2]. 'Timely Access' refers to the proportion of the population with access to Bellwether procedures within 2 hours. Bellwether procedures are defined by LCoGS as cesarean delivery, laparotomy, and open fracture [2]. In Mozambique, road conditions are highly variable due to the rainy season so timely access was defined as the population living in a geographic district with surgical capacity in the local community hospital. Provider density was calculated as the volume of surgeons, anesthesiologists, and obstetricians (SAO) per 100,000 population. Volume of surgery was calculated as the number of surgeries performed in an operating room per 100,000 population. Of note, volume of surgery was also calculated as an annualized density by doubling the six-month values of surgical procedures in the numerator to allow for comparison to other studies where annual values are the accepted standard. Postoperative mortality ratios (POMR) were calculated as the volume of in-hospital deaths after surgery (numerator) divided by the total volume of surgical cases (denominator). Secondary outcomes

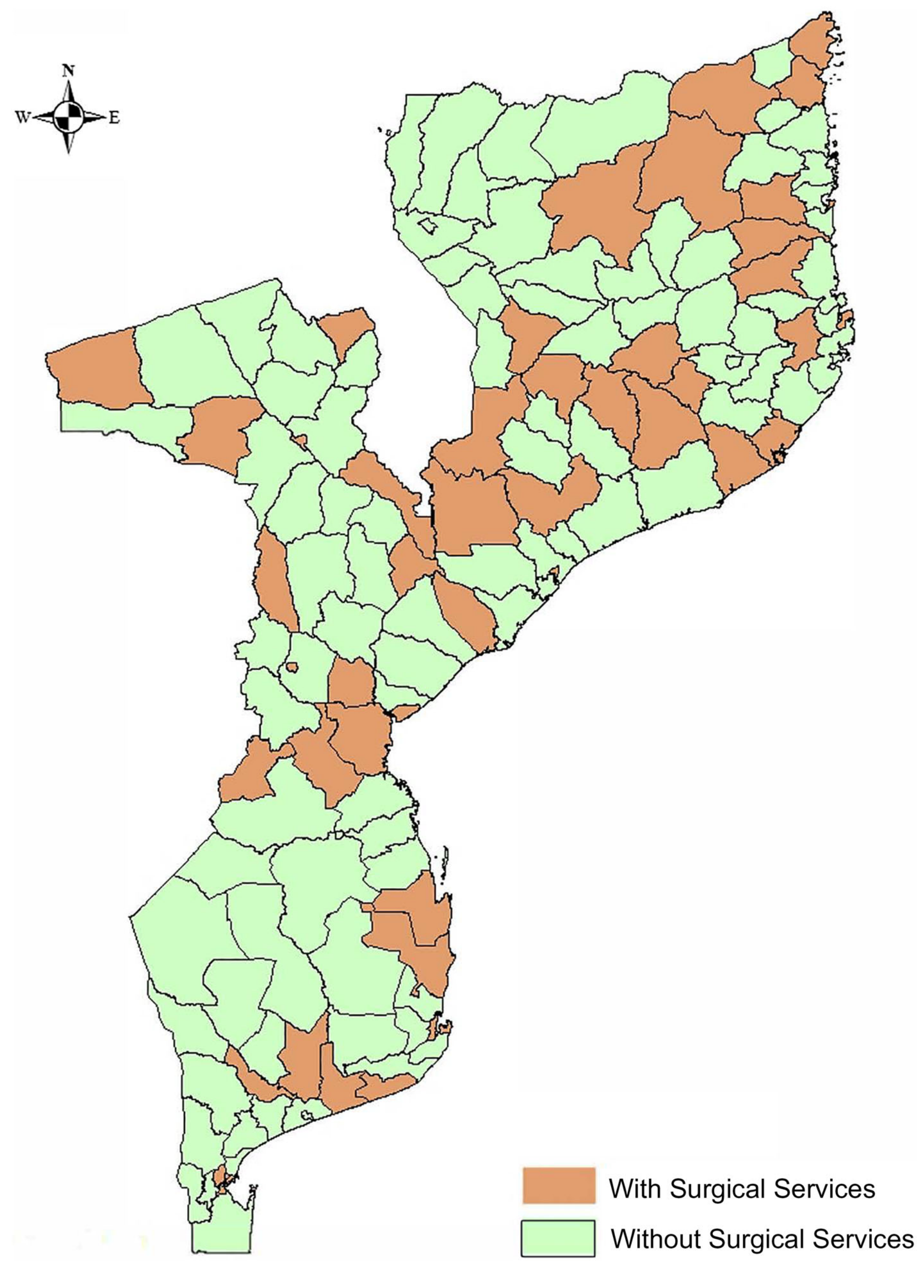

Fig. 1 Map of Mozambique showing 54 Districts with surgical capacity (in orange) and those without surgical capacity (in green)

of nonphysician technician densities (per 100,000 population) were also calculated in a similar fashion for surgical technicians, anesthesia technicians, and obstetric technicians. All calculations were performed at the national level and again by geographic Province. Demographic data and population denominators were taken from the Mozambique's Ministry of Health [20]. Data definitions are also consistent with the WHO's Global Reference List of 100 Core Health Indicators and WB's World Development Indicators [9, 9]. Econometrics data such as catastrophic expenditure and impoverishing expenditure were not collected.

Results

Summary: national demographics and infrastructure

We identified 54 hospitals with surgical capacity with 130 total operating rooms (0.5 OR per 100,000 people) where 47,189 surgical encounters occurred (Table 1). Three of these health facilities were regional hospitals, 12 were provincial hospitals, and 39 were district (aka rural) hospitals. Most of Mozambique's population (68.2%) resides in rural areas, and the gender distribution is roughly equal

Table 1 Provinces of Mozambique and their characteristics, including population, rurality, gender distribution, operating rooms, timely access, surgical–anesthesia–obstetric technicians, and surgical–anesthesia–obstetric physicians

Province	Population	Rurality		Gender Distribution		Operating Rooms (Density)	Timely Access		SAO Technicians (Density)	SAO (Density
		Rural (%)	Urban (%)	Female (%)	Male (%)		Without (%)	With (%)		
Maputo city	1,241,702	0 (0)	1,241,702 (100)	644,593 (51.9)	597,109 (48.1)	16 (1.3)	0 (0)	1,241,702 (100)	59 (4.7)	122 (9.8)
Maputo province	1,709,058	508,192 (29.7)	1,200,866 (70.3)	889,850 (52.1)	819,208 (47.9)	6 (0.3)	518,199 (30.3)	1,190,859 (69.7)	27 (1.6)	14 (0.8)
Gaza	1,416,810	1,051,460 (74.2)	365,350 (25.8)	770,807 (54.5)	646,003 (45.6)	8 (0.6)	683,861 (48.3)	732,948 (51.7)	22 (1.5)	8 (0.6)
Inhambane	1,499,479	1,140,226 (76.0)	359,253 (24.0)	826,194 (55.1)	673,285 (44.9)	11 (0.7)	766,027 (51.1)	733,451 (48.9)	35 (2.3)	16 (1.1)
Manica	1,933,522	1,472,925 (76.2)	460,597 (23.8)	1,000,797 (51.8)	932,725 (48.2)	8 (0.4)	1,115,753 (57.7)	817,768 (42.3)	26 (1.3)	8 (0.4)
Sofala	2,048,676	1,311,173 (64.0)	737,503 (36.0)	1,053,840 (51.4)	994,836 (48.6)	16 (0.8)	665,545 (32.5)	1,383,131 (67.5)	32 (1.5)	26 (1.3)
Tete	2,517,444	2,176,059 (86.4)	341,385 (13.6)	1,285,484 (51.1)	1,231,960 (48.9)	12 (0.5)	1,444,193 (57.4)	1,073,252 (42.6)	25 (1.0)	23 (0.9)
Zambezia	4,802,365	3,794,084 (79.0)	1,008,281 (21.0)	2,482,815 (51.7)	2,319,550 (48.3)	13 (0.3)	2,097,421 (43.7)	2,704,944 (56.3)	44 (0.9)	30 (0.6)
Nampula	5,008,793	3,393,495 (67.8)	1,615,298 (32.2)	2,535,547 (50.6)	2,473,246 (49.2)	19 (0.4)	2,229,246 (44.5)	2,779,549 (55.5)	38 (0.8)	42 (0.8)
Niassa	1,556,906	1,268,704 (76.6)	388,202 (23.4)	842,795 (50.9)	814,111 (49.1)	7 (0.4)	1,220,616 (73.7)	436,290 (26.3)	11 (0.6)	14 (0.9)
Cabo Delgado	1,893,156	1,430,118 (75.5)	463,038 (24.5)	976,175 (51.6)	916,981 (48.4)	14 (0.7)	805,112 (42.5)	1,088,043 (57.5)	27 (1.4)	15 (0.8)
Mozambique	25,727,911	17,546,436 (68.2)	8,181,475 (31.8)	597,109 (48.1)	12,419,014 (48.3)	130 (0.5)	11,545,973 (44.9)	14,181,937	343 (1.3)	318 (1.2)

Key: SAO = Surgical–anesthesia–obstetric, all densities reported as per 100,000 population

(51.7% female, 48.3% male). Patients from all 11 geographic provinces were represented within the study cohort, including rural and urban settings. There are 318 certified SAO providers (1.2/100,000 population) and 343 nonphysician SAO technicians (1.3 per 100,000 population). More than 60% of the geographic districts in Mozambique do not have health facilities with operating rooms (and thus no SAO providers whatsoever), leaving 44.9% of Mozambique's population without timely access to surgical services (Fig. 1).

Provincial variability in infrastructure

Significant variability exists between provinces with regard to demographics and infrastructure (Table 1). The proportion of the population that lives in a rural setting varies from 0% in Maputo City to 86.4% in Tete Province; however, there is less variability outside of the capital city, Maputo, ranging from 64.0% rural in Sofala to 84.6% rural in Tete. The density of operating rooms ranges by a factor of four from 0.3 per 100,000 population in Zambezia and Maputo Provinces to 1.3 per 100,000 population in Maputo City. The proportion of the population without timely access to surgical services ranges from 0% in Maputo City to 73.7% in Niassa. In 8 of 11 provinces, at least 40% of the population lives in districts without surgical services.

Variability in workforce

Most Mozambican hospitals with surgical services had no accredited anesthesiologist or surgeon (Table1). Accredited SAO densities ranged by a factor of 20 from 0.4/100,000 in Manica Province to 9.8/100,000 in Maputo City. Thirty hospitals (55.5%) were without accredited surgeons, and 40 hospitals (74.1%) were without accredited anesthesiologists and rely strictly on nonphysician surgeon and anesthesiologist technicians (Table2). Nonphysicians provided 39.7% (18,769) of national surgical volume. Nationally, accredited anesthesia providers were fewer (0.1 per 100,000 population) than accredited surgeons (1.1 per 100,000 population). All provincial and regional hospitals had accredited surgeons and anesthesiologists. SAO densities for medical doctors, nonphysician technicians, and combined medical doctors plus nonphysician technicians are compared in Table 2.

Table 2 Summary of surgical workforce, including physicians and nonphysician technicians

Province	Surgery (density)		Anesthesia (density)		Obstetrics (density)		Total providers (density)		
	MD	Technician	MD	Technician	MD	Technician	MD	Technician	Combined
Maputo City	75 (6.0)	9 (0.7)	23 (1.8)	40 (3.2)	25 (2.0)	9 (0.7)	122 (9.8)	59 (4.7)	181 (14.5)
Maputo Province	7 (0.4)	8 (0.5)	1 (0.1)	5 (0.3)	6 (0.3)	14 (0.8)	14 (0.8)	27 (1.6)	40 (2.4)
Gaza	5 (0.4)	7 (0.5)	0 (0.0)	12 (0.9)	3 (0.2)	3 (0.2)	8 (0.6)	22 (1.5)	30 (2.1)
Inhambane	10 (0.7)	10 (0.6)	2 (0.1)	17 (1.1)	4 (0.3)	8 (0.5)	16 (1.1)	35 (2.3)	51 (3.4)
Manica	4 (0.2)	5 (0.3)	0 (0.0)	17 (0.9)	4 (0.2)	4 (0.2)	8 (0.4)	26 (1.3)	34 (1.8)
Sofala	19 (0.9)	6 (0.3)	2 (0.1)	24 (1.2)	5 (0.2)	2 (0.1)	26 (1.3)	32 (1.5)	58 (2.8)
Tete	17 (0.7)	8 (0.3)	1 (0.0)	12 (0.5)	5 (0.2)	5 (0.2)	23 (0.9)	25 (1.0)	48 (1.9)
Zambezia	20 (0.4)	15 (0.3)	2 (0.0)	25 (0.5)	7 (0.1)	4 (0.1)	30 (0.6)	44 (0.9)	73 (1.5)
Nampula	30 (0.6)	12 (0.2)	3 (0.1)	24 (0.5)	9 (0.2)	3 (0.1)	42 (0.8)	38 (0.8)	80 (1.6)
Niassa	11 (0.7)	3 (0.2)	1 (0.1)	7 (0.4)	2 (0.1)	1 (0.0)	14 (0.9)	11 (0.6)	25 (1.5)
Cabo Delgado	10 (0.5)	9 (0.5)	2 (0.1)	13 (0.7)	3 (0.2)	5 (0.3)	15 (0.8)	27 (1.4)	42 (2.2)
Mozambique	209 (0.8)	90 (0.3)	37 (0.1)	196 (0.8)	72 (0.3)	57 (0.2)	318 (1.2)	343 (1.3)	661 (2.6)

Key: MD = Medical Doctor. All densities reported per 100,000 population

Table 3 Summary of surgical output, including surgical case volume, annualized surgical case volume, surgical case volume density (per 100,000), surgical case volume per operating room (OR), deaths within 24 h of surgery, 24-h postoperative mortality rate (POMR), and in-hospital (total) postoperative mortality rate (POMR)

Province	Case volume	Case volume annualized	Case volume density*	Case volume per OR	Deaths in 24Hrs (POMR, %)	Deaths, Total (POMR, %)
Maputo City	11,779	23,558	1897	1472	5 (0.04)	46 (0.39)
Maputo Province	1728	3456	202	576	3(0.17)	4 (0.23)
Gaza	1796	3592	254	449	3 (0.17)	13 (0.72)
Inhambane	3664	7328	489	666	6 (0.16)	13 (0.35)
Manica	2305	4610	238	576	5 (0.22)	11 (0.48)
Sofala	4174	8348	407	522	12 (0.29)	32 (0.77)
Tete	3377	6754	268	563	11 (0.33)	30 (0.89)
Zambezia	4324	8648	180	665	19 (0.44)	47 (1.09)
Nampula	8647	17,294	345	910	17 (0.20)	95 (1.10)
Niassa	1569	3138	189	448	8 (0.51)	28 (1.78)
Cabo Delgado	3826	7652	404	547	10 (0.26)	29 (0.76)
Mozambique	47,189	94,378	367	726	99	348 (0.74)

*case volume density is annualized case volume

Surgical output

There were 47,189 surgical procedures performed during the six-month study period (Table 3). Annualized national surgical case volume was 367 procedures/100,000 population and ranged from 180/100,000 in Zambezia Province to 1,897/100,000 in Maputo City. As a measure of resource utilization, annualized case volume per OR was 726 nationally and ranged from 448 in Niassa to 1,472 in Maputo City. There were 99 deaths within 24 h of surgery, with a 24-h POMR of 0.21%. There were 348 total deaths that occurred in the hospital after surgery with a POMR of 0.74%. The inpatient POMR varied by province, ranging from 0.23% in Maputo Province to 1.78% in Niassa Province (Fig. 2).

Discussion

Our findings highlight significant shortcomings in the provision of surgical care in Mozambique. The comprehensive nature of this study facilitates the identification of population-level deficiencies at multiple levels of the healthcare system, in both urban and rural settings, and

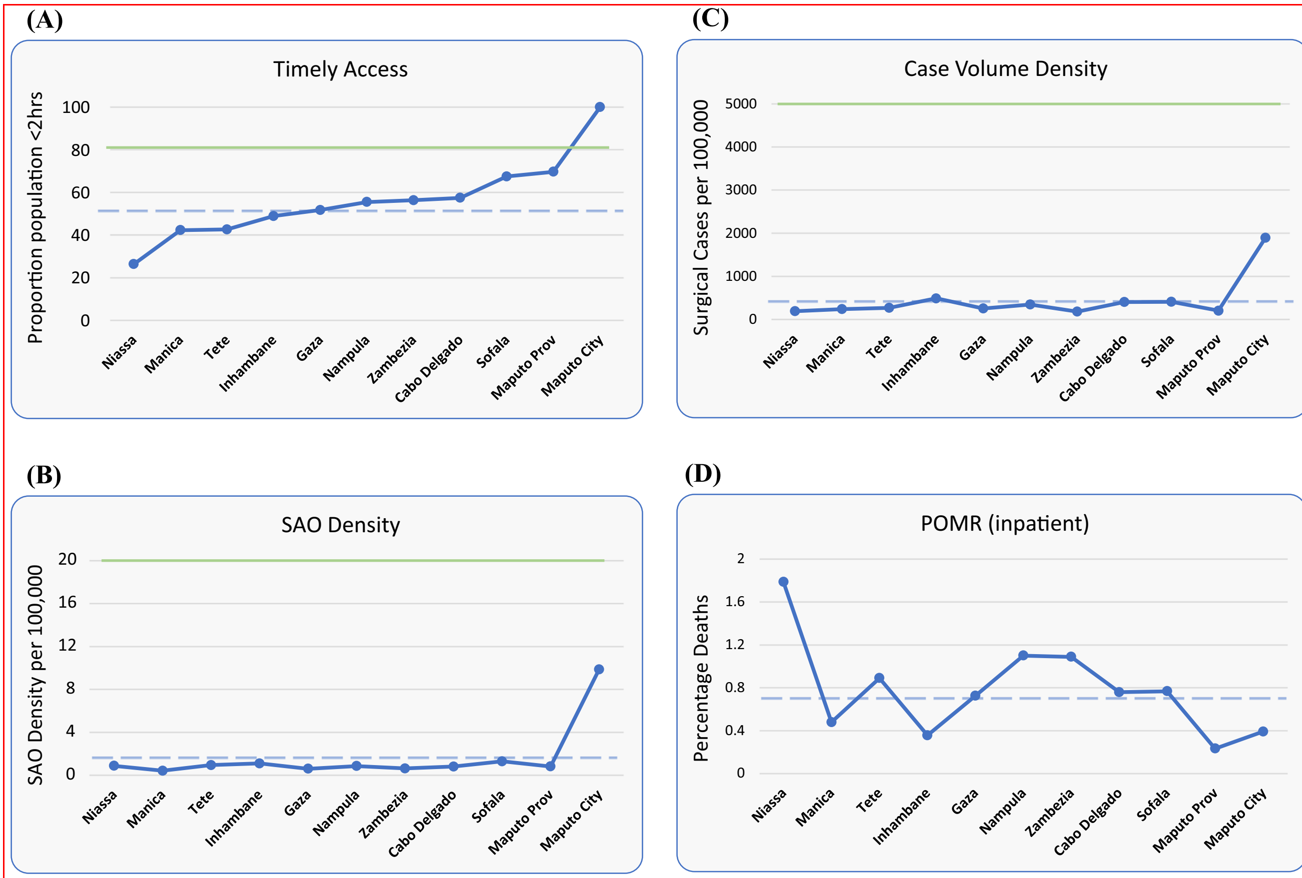

Fig. 2 Summary of key surgical indicators in Mozambique; namely **a** proportion of population with timely access, **b** density of surgical, anesthesia, and obstetric (SAO) providers, **c** density of surgical case volume, and **d** postoperative mortality rate (POMR). Data are stratified by Province, with national values in blue (dotted) and international targets in green (solid). There is no consensus or international target for POMR

includes all patients undergoing surgery. Adoption of validated global surgery metrics confirms the feasibility and utility of facility-based data collection in austere environments according to recommendations from the WHO and WB.

Infrastructure

Poor access to surgery in Mozambique is directly linked to physical infrastructure. Worldwide, there are 6.2 ORs per 100,000 population [21, 22]. Mozambique's 0.5 ORs per 100,000 falls substantially below international comparisons, with 10 ORs per 100,000 in high-income countries and 1.2 ORs per 100,000 in Rwanda, a country in a similar economic tier [22, 23]. In Mozambique, 60% of geographic districts do not have ORs whatsoever, leaving 44.9% of the population without timely access to surgical services as they must travel to adjacent districts where surgical services are available. Infrastructural deficiencies reinforce the application of the 'Three Delays Framework' originally describing obstetric emergencies [2, 24].The 'Second Delay' in reaching care directly reflects physical infrastructure, and our study resonates with findings by Faierman et al. showing that patients seeking surgery traveled longer distances than any other group of (non-surgical) patients in Mozambican hospitals [25, 26].Without significant investment in infrastructure, Mozambique will fall short of the Lancet Commission on Global Surgery's target of 80% of the population with timely access by 2030 [2, 27].

Workforce

Our assessment of MNHS hospitals illustrates major deficits in the surgical, anesthesia, and obstetric (SAO) workforce in comparison with international targets that are best revealed by data stratification. Based on estimates from 2015 in 154 countries, national SAO density (per 100,000 population) ranges from 68 in high-income countries to 0.7 in low-income countries, and low-income countries are struggling to make progress [10]. Mozambique's national

SAO density of 1.2 per 100,000 is comparable to its low-income peers and far below the international target of 20 [2, 10]. Stratification by province reveals severe disparities as most surgical providers are heavily concentrated in the capital city of Maputo, where the SAO density is 9.8 compared to the median value of 0.84 in the Province of Nampula. Stratification by provider type also reveals densities of 1.1 surgeons and 0.1 anesthesiologists per 100,000 population. While a formal analysis is outside the scope of the current study, there are various possible explanations for the unequal distribution of providers, most notably the comparative luxuries of living in the urban capital setting.

Additionally, most district hospitals rely on nonphysician technicians to perform basic surgery and anesthesia. Traditionally, nonphysician technicians are not counted in international SAO comparisons, but in Mozambique these technicians provide 39.7% of all procedures and it is impossible to neglect their contribution. These technicians are compared in Table2 to demonstrate the effect of inclusion on national and subnational SAO calculations [10, 28]. More intense focus on surgical providers will be required to overcome the current barriers in the provision of safe surgical and anesthetic care [29–32].

Surgical output

Low surgical volume in Mozambique is multifactorial and granular data elucidates possible areas for improvement. Mozambique's annualized surgical case volume density of 367 per 100,000 falls well below the minimum international target of 5000 cases per 100,000 per year [2]. Stratification by province shows more than a tenfold difference in case volume density between the capital city Maputo and rural areas (i.e., Zambezia, Niassa). This 'tale of two metrics' between rural and urban settings is not unique [10, 33]. A study in Mozambique, Tanzania, and Uganda found low rates of major surgeries at district hospitals, ranging from 50 to 450 surgical procedures per 100,000 people, and that the majority of non-obstetric surgery is for emergencies rather than for elective conditions, suggesting that district residents do not receive surgical care for common (non-emergent) surgical conditions in local hospitals [34]. Community-based surveys also show that 17% of people in Mozambique are living with untreated surgical conditions [35, 36]. Our findings confirm that Mozambique will need to significantly boost its health system to reach recommended targets.

Postoperative mortality

Postoperative mortality (POMR) is unique among recommended surgical metrics because it is a marker of quality of surgical care [37–39]. In Mozambique, the national inpatient POMR was 0.74% and quite comparable to the Pacific Region [28]. However, stratification by province reveals substantial disparities between regions of the country, with POMRs spanning a range of roughly a tenfold difference (0.23% in Maputo Province to 1.78% in Niassa, See Table 3). This finding recapitulates the importance of comprehensive population-level datasets. Datasets relying on a convenience sample of self-selected institutions reporting POMR have limited utility in regional or international comparisons because they are not representative of the population outside the study [40–43]. The same is true of datasets limited to a discrete number or type of operations [44, 45]. These limitations of comparability are evident in the largest meta-analysis of POMR to date by Ng-Kamstra et al. [46]. In Mozambique, variation in POMR allows concentrated deeper dives in provinces of concern to disambiguate between the many possible causes of elevated POMR, including pre-hospital care, management of comorbid disease, timeliness of presentation, availability of resources, and quality of surgical care.

Strategies for incremental upscaling

The strength of our findings is most clearly elucidated in the exercise of implementing change. Aspirational targets, such as a surgical procedure volume density of 5000 cases per 100,000 population, seem out of reach from a setting like Mozambique where the starting point is 367 per 100,000. To put that into perspective, Mozambique's current national surgical volume output (94,378 cases annually) is only 7% of that goal. In order to achieve this goal, Mozambique surgical output would have to perform an additional 1,286,396 surgical procedures each year. Lowering the target to Maputo City's surgical output, 1897 cases per 100,000, makes the goal more attainable, which would require 393,680 additional surgical procedures each year. A more conservative strategy is to bring all provinces to the national statistic of 367 cases per 100,000 population, in which case efforts could be focused on the seven provinces that fall below this national average, which would require an additional 22,402 procedures each year, or 679 operations per hospital in those seven provinces, which translates to roughly 14 more operations per week. Incremental targets, grounded in subnational data stratifications, allow countries to set concrete short- and long-term goals on a path to upscaling surgical services with neighboring provinces serving as case studies of feasibility.

Our subnational findings also facilitate the development of referral networks within a country's healthcare system. In high-income countries, a robust body of literature confirms the positive relationship between hospitals with high surgical volume and postoperative outcomes [47]. High-volume centers are known to have lower postoperative mortality and costly complications [48]. For this reason, a logical response to the subnational disparities we report may include preferential triage of complex cases to centers where specialist care is available and ensuring availability of complex services to the frontline where acuity may not allow for immediate transfer without stabilization, such as trauma and obstetric emergency. Using a national dataset of surgical encounters from New Zealand, Hider et al. described a framework of four disease prototypes that allows policy-makers to apportion surgical services within a healthcare system according to disease prevalence and surgical incidence [49].

Weaknesses

The current study does have multiple weaknesses. Regarding access, our calculation is not ideal because we do not utilize available technologies such as ArcGIS, Redivis, or OpenStreetMaps [5, 50, 51]. During the rainy season in Mozambique, road conditions change drastically, leading to significant seasonal variability in access. The authors felt this variability was so great as to render the geospatial mapping without internal validity. Additionally, patient age, procedure type, ASA class, and emergency status might assist in risk adjustment through an efficient tool designed by the authors [52, 53]. Risk adjustment might help to account for differences between hospitals in case mix and disease severity. Lastly, we know that up to 30% of admissions to surgical wards in Mozambique do not undergo a surgical procedure, reflecting the large non-operative component of care by surgical teams that is wholly ignored by the standard metrics [26].

Summary

This is the first national study to address the delivery of surgery in Mozambique. Timely access, SAO provider density, and surgical case volumes in Mozambique fall short of international targets and substantial variation exists between provinces. Training and retaining local anesthesia and surgical physicians are vital to boost surgical services. Abject deficiencies and variations in surgical care pose targets for future interventions in advancing Mozambique's NSOAP. POMR is low and nonphysician technicians play a large role in this success. This study serves as a template for LMICs to follow in meeting the current mandates for surgical metrics from the WHO and the WB and establishes baseline outcomes for international comparisons and quality improvement.

Acknowledgements We would like to acknowledge Dr. Ussene Isse and all his team as the National Director of the Medical Assistance Directorate at the Ministry of Health of Mozambique. We also wish to thank our staff and collaborators at the Mozambique Institute for Health Education and Research (MIHER) who gave the institutional and administrative support which made this work possible. A special thanks to my research team, Drs. Adriano Tivane, Amâncio Oliveira, Clotilde Nhatave, Ivandra Magaia, Micail Julaya, Monica Muataco, Nelson Mucopo, Paulo Gudo, Thiago Machado de Oliveira, Tyler Robinson, Jamie Anderson, all the nonphysician surgeons, administrative personnel, and health managers who took part in this work.

Funding This project was supported by United States National Institutes of Health through the Fogarty International Center and University of California Global Health Institute (UCGHI), grant numbers R25TW009343 and R25TW011216.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest of relevant financial disclosures.

References

1. Bickler SW, Weiser TG, Kassebaum N, Higashi H, Chang DC, Barendregt JJ (2015) Global burden of surgical conditions. In: Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN (eds) Disease control priorities. The World Bank, Washington
2. Meara JG, Leather AJ, Hagander L, Ismail EA, Alkire BC, Alonso N et al (2015) Global Surgery 2030: evidence and solutions for achieving health, welfare and economic development. Lancet 386(9993):569–624
3. Shawar YR, Shiffman J, Spiegel DA (2015) Generation of political priority for global surgery: a qualitative policy analysis. Lancet Glob Health 3(8):e487–e495
4. Hsia RY, Mbembati NA, Macfarlane S, Kruk ME (2011) Access to emergency and surgical care in sub-Saharan Africa: the infrastructure gap. Health Policy Plan 27(3):234–244
5. Alkire B, Raykar N, Shrime M, Weiser T, Bickler S, Rose J et al (2015) Global access to surgical care: a modeling study. Lancet Glob Health 3:e316–e323
6. Rose J, Weiser TG, Hider P, Wilson L, Gruen R, Bickler SW (2015) Estimated need for surgery worldwide based on prevalence of diseases: implications for public health planning of surgical services. Lancet Glob Health 3(52):S13-20
7. Verguet S, Alkire BC, Bickler SW et al (2015) Timing and scaling up surgical services in low-income and middle-income countries from 2012 to 2030: a modelling study. Lancet Glob Health 3:S28–S37
8. Resolution A 68/15: Strengthening emergency and essential surgical care and anaesthesia as a component of universal health coverage. 2015. http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_R15-en.pdf?ua=1. Accessed 19 June 2019
9. Global reference list of 100 core health indicators. 2015. https://www.who.int/healthinfo/indicators/2015/en/. Accessed 19 Jun 2019
10. World development indicators, 2016. http://datatopics.worldbank.org/world-development-indicators/. Accessed 19 Jun 2019
11. Holmer H, Bekele A, Hagander L et al (2019) Evaluating the collection, comparability, and findings of six global surgery indicators. BJS 106:e138–e150
12. Truche P, Shoman H, Reddy CL et al (2020) Globalization of national surgical, obstetric, and anesthesia plans: the critical link

between health policy and action in global surgery. Glob Health 16(1):1
13. Gajewsky J, Bijlmakers L, Brugha R (2018) Global surgery: informing natinal strategies for scaling up surgery in sub-Saaharan Africa. Int J Health Policy Manag 7(6):481–484
14. World Health Organization (WHO). Global health observatory data. https://www.who.int/gho/publications/world_health_statistics/en/. Accessed 19 Jun 2019
15. United Nations Development Program (UNDP). Human development report 2016: Human development for everyone. http://hdr.undp.org/sites/default/files/HDR2016_EN_Overview_Web.pdf. Accessed 19 Jun 2019
16. World Health Organization (WHO). World health report 2006 - working together for health: WHO; 2006 [Annex Table 4 Global distribution of health workers in WHO Member States]. http://www.who.int/whr/2006/en/. Accessed 19 June 2019
17. Health MO. Livro de Registo de especialistas. Ordem dos Medicos de Moçambique. (2015)
18. DNAM-MISAU. Relatorio Anual da DNAM - Ano 2015. Ministry of Health. (2015)
19. Vaz F, Bergström S (1999) Training medical assistants for surgery. Bull World Health Organ 77(8):688
20. National Institute of Statistics. Mozambique in Numbers 2014. Maputo, Mozambique: Instituto Nacional de Estatistica; 2015 May 2015. http://www.ine.gov.mz. Accessed 19 Jun 2019
21. National Institute of Demographic Statistics (IND). PIB per capita. http://www.ine.gov.mz/estatisticas/estatisticas-economicas/contas-nacionais/anuais-1/pib_percapita.xlsx/at_download/file. Accessed 19 Jun 2019
22. Weiser TG, Makary MA, Haynes AB, Dziekan G, Berry WR, Gawande AA et al (2009) Standardised metrics for global surgical surveillance. Lancet 374(9695):1113–1117
23. Funk LM, Weiser TG, Berry WR, Lipsitz SR, Merry AF, Enright AC et al (2010) Global operating theatre distribution and pulse oximetry supply: an estimation from reported data. Lancet 376(9746):1055–1061
24. Petroze R, Nzayisenga A, Rusanganwa V, Ntakiyiruta G, Calland J (2012) Comprehensive national analysis of emergency and essential surgical capacity in Rwanda. Br J Surg 99(3):436–443
25. Thaddeus S, Maine D (1994) Too far to walk: maternal mortality in context. Soc Sci Med 38:1091–1110
26. Faierman ML, Anderson JE, Assane A, Bendix P, Vaz F, Rose J, Funzamo C, Noormahomed E, Bickler S (2014) Surgical patients travel longer distances than non-surgical patients to receive care at a rural hospital in Mozambique. Int Health 7(1):60–66
27. Anderson JE, Erickson A, Funzamo C et al (2014) Surgical conditions account for the majority of admissions to three primary referral hospitals in rural Mozambique. World J Surg 38(4):823–829. https://doi.org/10.1007/s00268-013-2366-1
28. Chao TE, Sharma K, Mandigo M et al (2014) Cost-effectiveness of surgery and its policy implications for global health: a systematic review and analysis. Lancet Glob Health 2:e334–e345
29. Guest GD, McLeod E, Perry WRG et al (2017) Collecting data for global surgical indicators – a collaborative approach in the Pacific Region. BMJ Glob Health 2:e000376
30. Noormahomed EV, Mocumbi AO, Preziosi M et al (2013) Strengthening research capacity through the medical education partnership initiative: the Mozambique experience. Hum Resour Health 11:62
31. Collins FS, Glass RI, Whitescarver J, Wakefield M, Goosby EP (2010) Developing health workforce capacity in Africa. Science 330:1324–1325
32. Cancedda C, Cotton P, Shema J et al (2018) Health professional training and capacity strengthening through international academic partnerships: the first five years of the Human Resources for Helath program in Rwanda. J Health Policy Manag 7(11):1024–1039
33. Daniels KM, Riesel JN, Verguet S, Meara JG, Shrime MG (2019) The scale-up of the global surgical workforce: can estimates be achieved by 2030? World J Surg. 44:1053–1061. https://doi.org/10.1007/s00268-019-05329-9
34. Weiser TG, Hayne AB, Molina G et al (2016) Size and distribution of the global volume of surgery in 2012. Bull World Health Organ 94(3):201-209F
35. Galukande M, von Schreeb J, Wladis A, Mbembati N, de Miranda H, Kruk ME et al (2010) Essential surgery at the district hospital: a retrospective descriptive analysis in three African countries. PLoS Med 7(3):e1000243
36. Rose J, Bendix P, Funzamo C, Vaz F, Assis da Costa A, Bickler S, Noormahomed E (2015) The Universidade Eduardo Mondlane-University of California, San Diego surgical research partnership. Bull Am Coll Surg. 100(1):27–34
37. Bendix P, Funzamo C, Vaz F, Assan A, Noormahomed E, Bickler S (2013) The burden of surgical conditions in three rural communities in Mozambique. Paper presented at: World Congress of Surgery, Obstetrics, Trauma and Anesthesia; October 16–17, 2013; Port of Spain, Trinidad and Tobago. http://www.hopkinscme.edu/CourseDetail.aspx/80031335. Accessed 27 Feb 2014
38. Watters DA, Hollands MJ, Gruen RL et al (2015) Perioperative mortality rate (POMR): a global indicator of access to safe surgery and anaesthesia. World J Surg 39:856–864. https://doi.org/10.1007/s00268-014-2638-4
39. Ariyaratnam R, Palmqvist CL, Hider P et al (2015) Toward a standard approach to measurement and reporting of perioperative mortality rate as a global indicator for surgery. Surgery 158:17–26
40. Kruk ME, Gage AD, Arsenault C et al (2018) High-quality health systems in the sustainable development goals era: time for a revolution. Lancet Glob Health 6:e1196–e1252
41. Biccard BM, Madiba TE, Kluyts HL, Munlemvo DM, Madzimbamuto FD, Basenero A et al (2018) African Surgical Outcomes Study (ASOS) investigators. Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. Lancet 391:1589–1598
42. Pearse RM, Moreno RP, Bauer P et al (2012) Mortality after surgery in Europe: a 7-day cohort study. The Lancet 380:1059–1065
43. Davies JF, Lenglet A, Wijhe MV, Ariti C (2016) Perioperative mortality: analysis of 3 years of operative data across 7 general surgical projects of Medecins Sans Frontieres in Democratic Republic of Congo, Central African Republic, and South Sudan. Surgery 159:1269–1278
44. Organization for Economic Co-Operation and Development (OECD). OECD.Stat. Health Care Utilization: surgical procedures. https://stats.oecd.org/index.aspx?queryid=30167. Accessed 19 June 2019
45. Eurostat. Statistics explained. Surgical operations and procedures statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php/Surgical_operations_and_procedures_statistics. Accessed 19 June 2019.
46. Ng-Kamstra JS, Arya S, Greenberg SLM et al (2018) Perioperative mortality rates in low-income and middle-income countries: a systematic review and meta-analysis. BMJ Glob Health 3:e000810
47. Birkmeyer JD, Siewers AE, Finlayson EVA et al (2002) Hospital volume and surgical mortality in the United States. N Engl J Med 346:1128–1137
48. Birkmeyer JD, Gust C, Dimick JB, Birkmeyer NJO, Skinner JS (2012) Hospital quality and the cost of inpatient surgery in the United States. Ann Surg 255(1):1–5

49. Hider P, Wilson L, Rose J, Weiser TG, Gruen R, Bickler SW (2015) The role of facility-based surgical services in addressing the national burden of disease in New Zealand: an index of surgical incidence based on country-specific disease prevalence. Surgery 158:44–54
50. Knowlton LM, Banguti P, Chackungal S et al (2017) A geospatial evaluation of timely access to surgical care in seven countries. Bull World Health Organ 95:437–444
51. Stewart BT, Tansley G, Gyedu A et al (2016) Mapping population-level spatial access to essential surgical care in Ghana using availability of Bellwether procedures. JAMA Surg 151(8):e161239
52. Anderson JE, Rose J, Noorbakhsh A et al (2014) An efficient risk adjustment model to predict inpatient adverse events after surgery. World J Surg 38(8):1954–1960. https://doi.org/10.1007/s00268-014-2490-6
53. Rose J, Greenberg S, Quinn JW (2015) NSQIP-lite: measuring surgical outcomes in Mozambique. The Case Center. Boston MA, Babson College

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