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Research Paper

Assessment of diagnostics capacity in hospitals providing surgical care in two Latin American states

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ABSTRACT

Background: Diagnostic services are an essential component of high-quality surgical, anesthesia and obstetric (SAO) care. Efforts to scale up SAO care in Latin America have often overlooked diagnostics capacity. This study aims to analyze the capacity of diagnostic services, including radiology, pathology, and laboratory medicine, in hospitals providing SAO care in the states of Chiapas, Mexico and Amazonas, Brazil.
Methods: A stratified cross-sectional evaluation of diagnostic capacity in hospitals performing surgery in Chiapas and Amazonas was performed using the Surgical Assessment Tool (SAT). National data sources were queried for indicators of diagnostics capacity in terms of workforce, infrastructure and diagnosis utilization. Fisher's exact tests and chi-square tests were used to compare categorical variables between the private and public sector in Chiapas while descriptive statistics are used to compare Amazonas and Chiapas.
Findings: In Chiapas, 53% (n = 17) of public and 34% (n = 20) of private hospitals providing SAO care were assessed. More private hospitals than public hospitals could always provide x-rays (35% vs 23.5%) and ultrasound (85% vs 47.1%). However neither sector could consistently perform basic laboratory testing such as complete blood counts (70.6% public, 65% private). In Amazonas, 30% (n = 18) of rural hospitals were surveyed. Most had functioning x-ray machine (77.8%) and ultrasound (55.6%). The majority of hospitals could provide complete blood count (66.7%) but only one hospital (5.6%) could always perform an infectious panel. Both Chiapas and Amazonas had dramatically fewer diagnostic practitioners per capita in each state compared to the national average capacity.
Interpretation: Facilities providing SAO care in low-resource states in Mexico and Brazil often lack functioning diagnostics services and workforce. Scale-up of diagnostic services is essential to improve SAO care and should occur with emphasis on equitable and adequate resource allocation.

1. Introduction

Diagnostic services, including radiology, pathology, and laboratory medicine, are an essential component of high quality surgical, anesthesia, and obstetric (SAO) care [1]. Such services dramatically influence each aspect of SAO care including the prevention, diagnosis, and treatment of surgical conditions. With diagnostic services, women can be screened for cervical cancer, anesthetic agents can be correctly titrated, and patients can receive safe blood transfusions, all of which can save lives and prevent disability. However, diagnostic services are often limited in low- and middle-income countries (LMICs) [2]. Just as diagnostic services support each component of SAO care, the lack of adequate diagnostic services weaken surgical systems, resulting in delayed diagnoses and poor quality treatments

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Research in context

Evidence before this study

A literature search was conducted using PubMed, Google Scholar, and reference reviews. Search criteria included publications assessing diagnostic services within a region or country. Diagnostic services included radiology, pathology, and laboratory medicine. Surgical care included all surgical specialties, anesthesia and obstetrics. Reports published in English, Spanish, or Portuguese were included. Additional evidence from in-country databases (Cubos Dinámicos, Pesquisa Nacional de Saúde - PNS and DataSUS) in the countries of interest (Mexico, Brazil) were queried. The search was performed between January and May 2020. The quality of the evidence was directly related to the potential biases of the report or database, and may include selection, recall, and observation bias. Overall there was limited evidence of studies that assessed the role of diagnostics capacity within a health system to provide surgical, obstetric and anesthesia care in resource limited settings.

Added value of this study

This study adds significant value to the understanding of the capacity of diagnostic services in relation to surgical services. There is a paucity of literature addressing the importance of diagnostic services and even less measuring its capacity in low resource settings. This study is one of the first to measure statewide diagnostic service capacity in Latin America with a lens on provision of surgical and anesthesia care.

Implications of all the available evidence

The findings of this study could inform policy decisions to improve diagnostic service capacity in the examined regions and to match diagnostics and surgical services to ensure high quality care. Furthermore, this study can be used as a guide for future research on how to assess and improve diagnostic service capacity in other regions globally. Finally, our results advocate for the urgent inclusion of diagnostics as an essential component of surgical systems.

[1]. Globally, 143 million additional surgical procedures are needed every year to address the unmet burden of surgical disease, particularly in LMICs [3]. As SAO care is scaled up, it is essential to ensure availability of high-quality diagnostic services.

While there have been efforts to evaluate and strengthen diagnostic capacity in several LMICs, the assessment of diagnostic services in Latin American countries has been largely overlooked [4,5]. Two such countries are Mexico and Brazil, they are both upper-middle-income countries that despite universal health coverage schemes, they have dramatic regional variations in healthcare access and quality [6–9]. Within Mexico and Brazil, the states of Chiapas and Amazonas, respectively, are some of the poorest states with the greatest challenges in accessing health care, particularly SAO care, largely due to limitations in workforce and infrastructure [10,11]. The challenges in providing safe, timely and affordable SAO care may be worsened by inadequacies in diagnostic services in these states.

The purpose of this study is to analyze the capacity of diagnostic services, including radiology, pathology, and laboratory medicine, in hospitals providing SAO care in the underserved states of Chiapas, Mexico and Amazonas, Brazil. By understanding patterns of distribution and availability of diagnostic services in these states, appropriate allocations and resource matching with SAO facilities can occur to maximize safe access to comprehensive surgical care for all.

2. Methods

2.1. Setting

The countries of Mexico and Brazil were chosen for this assessment as they are both upper-middle- income countries in Latin America and both have significant regional variations in healthcare access and quality despite having universal health coverage [7,8]. Within these two countries, the states of Chiapas and Amazonas, respectively, were selected as they are states with known challenges to healthcare access and may best elucidate challenges to diagnostic care [10,11]. The states were compared and found to have similar population demographics, GDP per capita, under five mortality rate, female life expectancy, human development indices and healthcare access and quality index (Table 1). Furthermore, the GDP per capita and educational attainment of both states is well below their respective national average.

Mexico has a social security system that provides health insurance to formal workers and their families [7,12]. For those outside the formal workforce, the public insurance scheme *Seguro Popular* provided insurance coverage for millions of low-income Mexicans until its recent replacement in January 2020 by the *Instituto de Salud para el Bienestar* [13]. This new system will aim to decentralize and integrate various public healthcare institutions to provide free care to all Mexicans in an efficient and coordinated manner [14]. In Chiapas, with a population of about 5.3 million, more than 80% of residents were

Table 1
Socioeconomic and healthcare comparison of Chiapas, Mexico and Amazonas, Brazil.

Metric	Chiapas, Mexico	Amazonas, Brazil
Population [43,44]	5217,908	4144,597
Under 5 mortality (per 1000 live births) [45,46]	21.0	21.4
Female life expectancy [45,46]	76.2	79.2
Fertility rate [45,46]	3.1	1.9
Indigenous population in the state (%) [11,47]	36.2	4.8
*Healthcare Access and Quality Index [45,46]	55.8	60.4
**Human Development Index (2010) [48,49]	0.656	0.674
GDP per capita in the state (nation) in USD [45,46]	10,311 (16,829)	11,917 (13,759)
Educational attainment in the state (nation) in years [45,46]	6.2 (8.3)	8.2 (8.6)
***Gini coefficient within the state (nation) [48,50,51]	56.6 (45.4)	66.6 (53.9)

*The Healthcare Access and Quality Index is measured on a scale from 0 (worst) to 100 (best) based on amenable mortality from 32 causes.
**Human Development index is a summary measure of average achievement in key dimensions of human development: Life expectancy at birth, expected years of schooling, mean years of schooling and gross national income per capita.
*** Gini coefficient is an indicator of economic inequality from 0 to 1 where the higher the number, the greater the income inequality.

enrolled in the government-funded *Seguro Popular* [12]. Despite a significant proportion of the population with public insurance, healthcare is delivered in both public and private hospitals [15,16]. In Brazil, the government's health scheme, *Sistema Único de Saúde* (SUS), is one of the largest public health care systems in the world, aiming to provide universal health coverage to all Brazilians [17]. However, specialist care availability varies regionally, with only 56% of physicians completing specialist training in the North region compared with 78% of physicians in the Southeast region [8,18]. The state of Amazonas, has a population of 4.1 million, with approximately 2 million residents living in remote rural areas outside the capital of Manaus [19].

2.2. Data collection tool and variables

Data was collected in Chiapas, Mexico and Amazonas, Brazil using the validated Surgical Assessment Tool (SAT, *Appendix A*) [20]. The SAT collects data from five surgical domains, including infrastructure, service delivery, information management, workforce, and financing. For the purpose of this study, we only present relevant data to diagnostics services from the infrastructure and service delivery domains. Specifically, the SAT collected data on electricity availability, functional imaging modalities, ability to perform blood transfusions, and laboratory capabilities. The SAT was translated into Spanish and Portuguese prior to implementation in Mexico and Brazil, respectively.

Electricity availability was included as many diagnostic services are reliant upon it to function. Functional imaging modalities included the frequency with which an x-ray, ultrasound, computed tomography (CT) machine, and magnetic resonance imaging (MRI) was functional and available. Laboratory capabilities referred to how frequently a facility was able to perform a complete blood count (CBC), complete metabolic panel (CMP), coagulation studies or infectious panel. A CBC includes values of red and white cell counts, hemoglobin, and platelets. A CMP measures blood levels of sodium, potassium, calcium, glucose, chloride, albumin, blood urea nitrogen, bicarbonate, total bilirubin and protein, and liver enzymes. Coagulation studies measure blood clotting times, including prothrombin time (PT) and activated partial thromboplastin time (aPTT), as well as coagulation factors. An infectious panel can test for infections including hepatitis and human immunodeficiency virus (HIV), and are critical for ensuring safe blood transfusions.

2.3. Sample and data collection

In both Amazonas and Chiapas, facilities were selected based on stratification of hospitals according to level of care and population served. The stratification was conducted to ensure a wide variety of hospitals were included in the sample. The data and analysis are not presented by strata, as the objective of the study was not to show diagnostics capacity by hospital level but instead to assess capacity of each state as a whole. In Chiapas, the SAT was implemented in public and private hospitals that perform at least one of the three surgical Bellwether procedures (laparotomy, management of open fracture, cesarean section) which have been identified as indicative of a facility's capability to provide a wide range of essential surgical services [21]. Public hospitals were stratified by level (community, general, federal) and by the ten health districts. In Mexico, community hospitals are defined as those providing general surgery services, while general hospitals are those providing gynecology and orthopedic surgery services in addition to general surgery [22]. Federal hospitals are defined as providing the specialties offered at lower level hospitals as well as additional subspecialties [23]. One hospital from each existing level in each of the ten health districts was sampled. The 57 private hospitals in Chiapas that perform at least one Bellwether procedure were invited to participate. Private hospitals were included if they verbally consented to completing the SAT. Data was collected in Chiapas from September 2019 to December 2019. In Amazonas, the SAT was implemented in public hospitals that provide surgical care outside of the capital city of Manaus as to capture the most remote populations in the state. The private sector does not play a role in surgical care in rural Amazonas and as a result were excluded [10]. Hospitals were stratified into quartiles based on catchment population and five hospitals were randomly chosen from each quartile. Stratification of hospitals was conducted solely to ensure a representative sample of different types of hospitals included in the analysis. Data collection in Amazonas occurred from July 2016 to March 2017. In both states, data was collected by in-country researchers (ZF, EM, RVF, JESS) who visited each hospital. The SAT was completed in collaboration with surgeons, anesthesiologists, obstetricians, surgical nurses, and/or administrators at each hospital.

Databases

Large national publicly available databases, Cubos Dinámicos (Mexico), Pesquisa Nacional de Saúde - PNS and DataSUS (Brazil), together with the national report on physicians Demografia Médica do Brasil were queried. Cubos Dinámicos is a publicly available database of health metrics from public hospitals established by the Mexican Ministry of Health [23]. Similarly, DataSUS is a database of national health information that is organized through the Brazilian Ministry of Health [24]. PNS is a national representative health survey organized by the Brazilian Institute of Geography and Statistics (IBGE), while Demografia Médica do Brasil is a report on brazilian physicians and specialists, its demographics and territorial distribution [24,25]. For the purposes of this study, population, surgical volume and workforce (pathologists, radiologists, and laboratory medicine specialists) were extracted [25,26]. These were used to estimate workforce density per 100,000 population in each of the states (Chiapas and Amazonas) compared with the national workforce density (Mexico and Brazil).

2.4. Statistical analysis

Descriptive statistical analysis was conducted, and Fisher's exact tests and chi-square tests were utilized to compare categorical variables as appropriate for sample sizes. These were used to compare diagnostics and laboratory services between private and public hospital in Chiapas only. A bivariate comparison was not conducted between Amazonas and Chiapas as these states are in different countries, serve different populations and have different health care systems. The comparisons between both states are meant to describe similar challenges in the provision of healthcare that poor rural states in upper-middle-income countries often experience. Workforce density per 100,000 population was calculated using the absolute specialist volume and state or country population. The analysis was performed using SAS Version 9.4 (Cary, NC) while data manipulation was performed using Excel Version 16.30 (Redmond, WA).

2.5. Ethical approval

Institutional Review Board (IRB) approval was obtained from the Chiapas Ministry of Health Bioethics Committee (#5003/8777), the University of Sao Paulo (#1904,101), Universidade do Estado do Amazonas (#1525,514) and was determined to be IRB exempt by Boston Children's Hospital in the United States. All participants were given details on the study and provided verbal consent prior to their enrollment and participation.

2.6. Role of funding

The funding source did not play any role in developing the research question, data analysis, interpretation or writing of the manuscript.

Table 2
Characteristics of hospitals included.

Setting	Percentage of Hospitals Sampled N (%)	Hospital Beds Median (IQR)	Always Functional Electricity N (%)*
Chiapas, Public	20 (34.5)	30 (40)	14 (82.4)
Chiapas, Private	17 (53.1)	7.5 (9.5)	19 (95)
Amazonas	18 (30)	23 (25)	6 (33.3)

* As responding with 100% to the SAT question: What percentage of the time does your hospital have functioning electricity?.

Table 3
Consistent availability of diagnostic imaging modalities in hospitals.

Imaging Modality	Amazonas N (%)	Chiapas N (%)		
		Public	Private	*p value*
Hospitals with always available, functioning X-Ray*	14 (77.8)	4 (23.5)	7 (35)	0.50
Hospitals with always available, functioning ultrasound*	10 (55.6)	8 (47.1)	17 (85)	0.01
Hospitals with always available, functioning CT*	1 (5.5)	0 (0)	3 (15)	0.23
Hospitals with always available, functioning MRI*	0 (0)	0 (0)	1 (5)	1

Data presented as absolute number of hospitals (percentage of sample). *p* values are for the comparison between public and private hospitals in Chiapas.

* As responding with 100% to the SAT question: What percentage of the time does your hospital have a functioning x-ray machine, ultrasound machine, CT, and MRI?.

3. Results

3.1. Hospital characteristics

In Chiapas, 41% (n = 37) of all public and private hospitals in the state were included, and 30% (n = 18) of all public hospitals outside of the state capital of Amazonas were included (Table 2). Within Chiapas, basic hospital infrastructure varied between the public and private sector. Private hospitals (median=7.5, IQR=9.5) had fewer beds than did public hospitals (median=30, IQR=40), but 95% of private hospitals (n = 19) always had functioning electricity compared with only 82% of public hospitals (n = 14). In Amazonas, the hospital beds median was 23 (IQR=25) and 33.3% (n = 6) of the sampled hospitals always had functioning electricity.

Diagnostic Services

In Chiapas, more private hospitals reported always having a functional x-ray, ultrasound, CT, and MRI machine compared with public hospitals (Table 3). 35% (n = 7) of private hospitals reported always having a functioning x-ray, while 60% (n = 12) never have an x-ray machine available (Fig. 1). Private hospitals had significantly more functional ultrasound machines than public hospitals (p = 0.01), while 23.6% (n = 4) of public hospitals had a functional ultrasound machine available less than 50% of the time (Fig. 2). In Amazonas, 77.8% of hospitals always had a functioning x-ray machine and 55.6% of hospitals always had a functioning ultrasound. One hospital in rural Amazonas and no public hospitals in Chiapas had a functioning CT. None of the hospitals assessed in either state had access to an MRI.

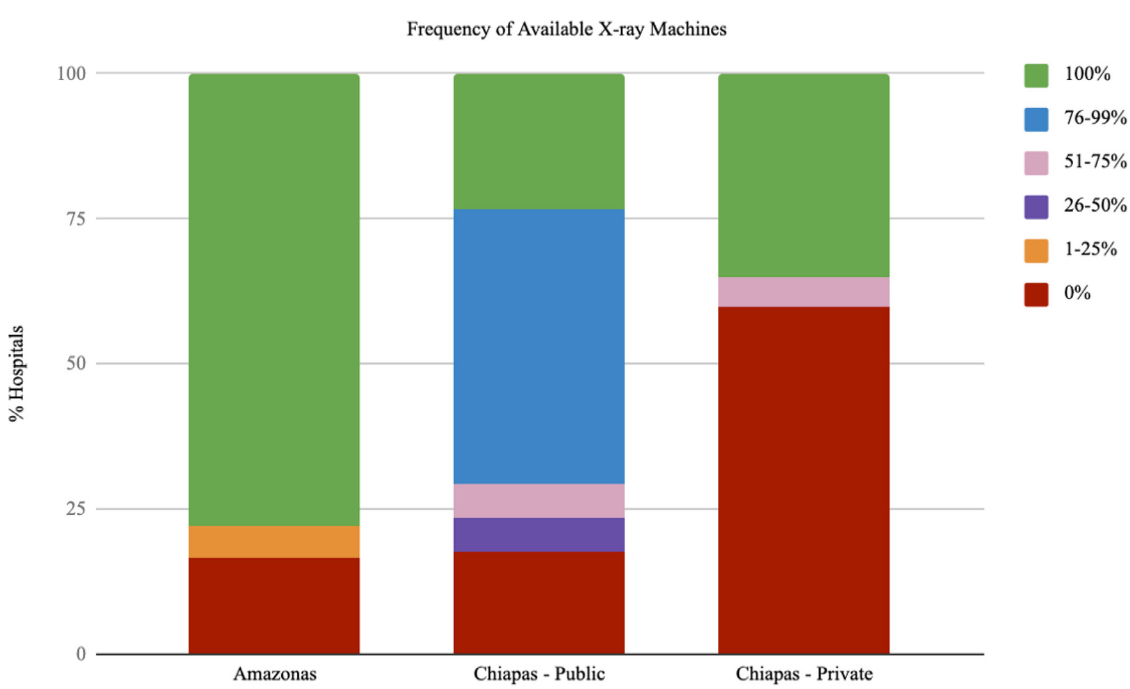

Fig. 1. Frequency of available x-ray machines.

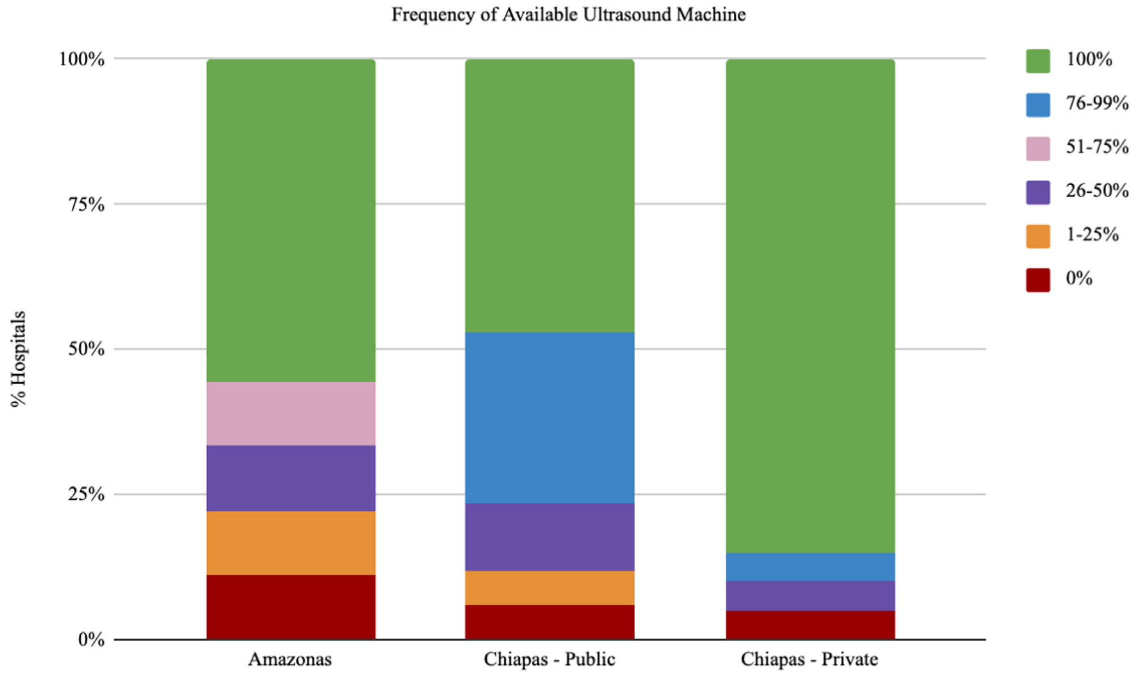

Fig. 2. Frequency of available ultrasound machines.

Table 4
Consistent availability of laboratory tests in hospitals.

Laboratory Modality	Amazonas N (%)	Chiapas N (%) Public	Private	*P value*
Hospitals always able to perform CBC[*,⦿]	12 (66.7)	12 (70.6)	13 (65)	0.74
Hospitals always able to perform CMP[*,§]	18 (100)	12 (70.6)	13 (65)	0.74
Hospitals always able to perform coagulation studies[*]	13 (72.2)	12 (70.6)	13 (65)	0.74
Hospitals always able to perform infectious panel[*]	1 (5.6)	9 (52.9)	13 (65)	0.46
Hospitals always able to perform blood transfusion in <2 hrs[*]	16 (86.9)	9 (52.9)	13 (65)	0.46

Data presented as absolute number (percentage). *p* values are for the comparison between public and private hospitals in Chiapas.

[*] As responding with 100% to SAT question: What percentage of the time is your hospital able to perform a CBC, CMP, coagulation panel, infectious panel, and blood transfusion in <2 hours

[⦿] CBC = Complete Basic Count.

[§] CMP = Complete Metabolic Panel.

3.2. *Laboratory services*

Not all hospitals in the public or private sector in Chiapas were able to perform basic laboratory testing all of the time, which includes a CBC, CMP, coagulation studies, and an infectious panel (Table 4). Among private hospitals, 65% (n = 13) could always perform CBC, CMP, coagulation studies, an infectious panel and provide a timely blood transfusion (Table 4). Comparatively, 70.6% (n = 12) of public hospitals were able to always perform a CBC, CMP or coagulation studies, whereas 53.9% (n = 9) could always perform an infectious panel and a timely blood transfusion. In Amazonas, 66.7% of hospitals could always perform a CBC, 100% could always perform a CMP, 72.2% coagulation studies, and 86.9% could provide blood transfusion under two hours. However, only one hospital (5.6%) could always perform an infectious panel.

3.3. *Workforce*

Nationally, Mexico has 3 radiologists, 1.2 anatomical pathologists, and 0.6 laboratory medicine physician providers per 100,000 population (Table 5). The state of Chiapas has fewer diagnostic specialists per capita than the national average in Mexico, with 1.1 radiologists, 0.5 anatomical pathologists, and 0.3 clinical pathology/ laboratory medicine providers per 100,000 people.

Table 5
Diagnostics specialist volume and density by country and state.

Diagnostics Providers	Brazil (9,42,47) (Population = 207,833,823) Per 100,000 (n)	Amazonas (9,18,47) (Population = 4144,597) Per 100,000 (n)	Mexico (43,51) (Population = 126,190,788) Per 100,000 (n)	Chiapas (22,44) (Population = 5217,908) Per 100,000 (n)
Radiologists	5.8 (12,233)	1.7 (72)	3.0 (3819)	1.1 (57)
Anatomical Pathologists	1.5 (3210)	0.6 (23)	1.2 (1511)	0.5 (25)
Laboratory Medicine/Clinical Pathology	0.7 (1450)	0.2 (9)	0.6 (758)	0.3 (16)

At the national level Brazil has a higher provider density than Mexico with 5.8 radiologists, 1.5 anatomical pathologists, and 0.7 laboratory medicine providers per 100,000 people. Fewer diagnostic specialists practice in Amazonas compared to the national average per capita, with 1.7 radiologists, 0.6 anatomical pathologists, and 0.2 laboratory medicine providers per 100,000 population.

4. Discussion

This study sought to assess diagnostic service capacity in hospitals providing surgical, anesthesia and obstetric care in two similar low-resource settings in Latin America, the state of Chiapas in Mexico and the state of Amazonas in Brazil. Our study indicates that hospitals providing SAO care do not always have access to functional diagnostic services and workforce that are essential for the delivery of surgical care. In both states, laboratory testing and diagnostic imaging was limited. Previous studies have evaluated diagnostic capacity in LMICs, although this is one of the first to analyze diagnostic services within the context of surgical capacity in Latin American countries [27].

Laboratory testing was inconsistently available among the sampled hospitals, with less than three-quarters of all hospitals reliably able to perform a CBC, coagulation panel, or infectious disease panel. Despite most hospitals in Amazonas having more reliable laboratory testing than those in Chiapas, only one hospital could always perform an infectious panel, compromising the ability to diagnose infectious diseases and the safety of patients and providers [28]. Furthermore, less than half of hospitals sampled in Chiapas could perform a blood transfusion in under two hours, a potentially fatal shortcoming for obstetric and trauma patients. Although the SAT tool does not specify availability of blood components such as platelets or plasma, these are also essential for high quality SAO care.

Diagnostic imaging, which could be the key distinguishing factor between performing emergency surgery or medically managing a patient, was minimal in both Chiapas and Amazonas. Functioning ultrasound equipment was only available in approximately half of public facilities. However, having functional equipment does not equate with trained radiologists or technicians being available on site. Another limitation was in CT and MRI imaging, with only one hospital in Amazonas and none of the public hospitals in Chiapas having an accessible CT or MRI machine. Although it would not be appropriate for small community hospitals to have a CT or MRI machine, larger hospitals in the public sector may need them to provide adequate subspecialty care. Referral pathways for patients to access adequate diagnostic and surgical care should be defined. Furthermore, while the private sector is often called upon to support shortcomings in the public sector, only 15% and 5% of private hospitals in Chiapas had access to a CT or MRI, respectively Ultimately, inconsistent diagnostic testing weakens the healthcare system, limiting the abilities of SAO treatment and compromising patient care [5].

The diagnostic workforce was limited in Chiapas and Amazonas. Although a target for diagnostic workforce density has yet to be established, Chiapas and Amazonas had dramatically fewer diagnostic practitioners per capita in each state compared with the national availability. Limitations in workforce can lead to inadequate resource matching in which diagnostic imaging or laboratory tests are underutilized due to the lack of trained diagnostic specialists. A study of diagnostic capacity in India found that care deficiencies resulted from a mismatch in diagnostic resources, ultimately resulting in increased cost to the healthcare system with worse healthcare outcomes [29]. In combating workforce shortages it is essential to address the cause, whether related to inadequate training or migration of providers. Especially in countries such as Mexico or Brazil with wide socioeconomic variance, diagnostic providers may seek to practice in regions with better compensation or infrastructure, as has been observed in sub-Saharan countries [30]. Emigration of diagnostic physicians from low-resource regions can exacerbate the limitations of diagnostic services, ultimately weakening the entire health ecosystem. Training of specialists in the underserved areas has been shown to help with workforce retention [31]. In Chiapas, the lack of residency training programs in radiology or pathology could be contributing to the diagnostics workforce shortage [32]. Ultimately, facilities providing surgical care in low-resource settings in Mexico and Brazil will need to improve not only their infrastructure but also their workforce of diagnostics specialists and technicians to strengthen diagnostics and overall health system capacity.

The limitations in diagnostic services in Mexico and Brazil compromise SAO care. In Brazil, inadequate and unevenly distributed diagnostic services have been described in the field of surgical oncology. Specifically, remote, resource-poor regions lack essential CT, MRI, or positron emission tomography-CT (PET-CT) imaging as well as trained pathologists, resulting in compromised cancer diagnosis and treatment [33]. In Mexico, mammographic equipment and trained personnel are insufficient, which has contributed to the rise in incidence and mortality of breast cancer [34]. Additionally, the majority of patients are treated with mastectomy as opposed to breast-conserving surgery, largely resulting from poor screening leading to more advanced disease presentation [35]. These deficiencies, specifically within infrastructure and workforce, are consistent with key shortcomings that affect other LMICs and also compromise surgical care quality and outcomes [4,5,36]. In sub-Saharan Africa, unreliable or inaccurate diagnostic testing has been shown to increase unnecessary system expenditures and lead to life-threatening misdiagnoses or delays in treatment [5]. In Uganda, a large portion of private hospitals providing surgical care do not have access to blood [37]. Furthermore, despite having less surgical volume than public hospitals, private facilities were often better equipped than public ones [37]. Reliable and accessible diagnostic services are paramount to SAO treatment, from cross-matching blood products, to safely titrating anesthetics, to using histopathology to determine disease type and treatment [1]. Diagnostic services and SAO treatment are intimately linked, and scale-up of diagnostic services is urgently needed to enable high-quality SAO care.

Diagnostic services must be scaled in a manner that considers resource allocation, resource matching, and private-public partnerships in order to maximize resource utilization and minimize cost in low-resource settings like Chiapas and Amazonas [29,38]. Specification of the resources and workforce that should be always available in a facility performing essential SAO care must be outlined. The stratification of resources and staffing required in each hospital at each care level should be determined in order to adequately allocate, repair, and budget for essential diagnostic services. Currently there are no global guidelines outlining minimal standards of diagnostics required for surgical care [2]. Once this is outlined, scale-up or reallocation with careful attention to resource matching, such as pairing an imaging technician with an x-ray machine, should occur to eliminate resource or workforce underutilization. In Chiapas and Amazonas, emphasis should be placed on strengthening the public sector to increase diagnostic imaging, laboratory testing, and specialists in tandem, with careful monitoring of resource utilization and specialist quantity. Additionally, in Chiapas where a private sector exists, private-public partnerships could be explored to take advantage of existing resources and personnel [38]. For example, diagnostic imaging could be outsourced to private facilities where there is better infrastructure, in order to utilize functioning equipment and avoid expensive purchases or repairs. But while patients may often seek services at private facilities due to unavailability of free or low-cost services at public hospitals, financial risk protection for these services should also be considered. The private sectors could receive subsidies for service provision from the public sector such that a mutually beneficial partnership may develop while strengthening diagnostic - and SAO - care overall.

In order to successfully scale diagnostic services, it is necessary for a country to develop a national strategic diagnostics plan (pathology, laboratory medicine and radiology) that is integrated into national healthcare delivery [3,39]. Such national plans are feasible, as demonstrated by the development and implementation of National Surgical, Obstetric, and Anesthesia Plans (NSOAPs) in many countries [40,41]. However, the scaling of SAO care should be paralleled by the scaling of diagnostic services, as SAO care is dependent upon and strengthened by a robust diagnostic system. These plans should also take into consideration other relevant existing health policies such as national cancer care plans given the large overlap between health care services. By implementing a plan to scale diagnostic and SAO services at the national level, federal resources can be utilized to prioritize vulnerable populations in poor regions of the country. Additionally, implementation at the national level allows for strategic planning to take into account the financial limitations of state or regional healthcare systems that exist in both Mexico and Brazil, as well as many other Latin American countries [42]. As a key component of a national plan, indicators and targets should be developed and regularly assessed in order to monitor the progress in scaling up diagnostic and SAO services. Through careful data analysis, resources and workforce can be calibrated to be efficient and cost-effective in resource-poor regions.

This study has the following limitations. The SAT tool administration can result in recall bias and subjectivity on the part of the respondent, therefore a more objective assessment that verifies the availability of resources throughout the year would result in more robust data. Additionally, our analysis was limited to one state per country and only included one third of the private hospitals in Chiapas. This is not representative of the whole country and does not consider the socioeconomic variability of the states in both countries. However, we intentionally wanted to focus on access to diagnostics for surgery in some of the most underserved states of Mexico and Brazil. Workforce volume data may be limited by physicians working in both public and private sectors, as well as some physicians not performing clinical work but instead holding administrative or research positions. Finally, data on the quantity of equipment in both countries was collected from large national databases which do not differentiate between functional and non-functional equipment. More detailed data such as availability of blood and other cultures could also be considered for future studies.

In conclusion, facilities providing surgical care in the low-resource states of Chiapas and Amazonas consistently lack essential diagnostics services and adequate workforce. To improve high-quality SAO care, diagnostic services must be improved and scaled. National strategic planning for diagnostics should be fully integrated with SAO planning and the overall national health strategy to ensure coordinated implementation and funding of services. Robust facility level data is essential to identify and address the gaps in diagnostic care for surgery. Consensus on global indicators that could measure and track progress on diagnostics capacity scale up are key to establish benchmarks and to inform policy. Diagnostic services are an essential component of a functioning health system and funding for capacity building must take them into consideration. Despite universal health coverage in Mexico and Brazil, lack of diagnostics services in its most vulnerable states could compromise access to high quality SAO care.

Author contributions

LR, ZF, JES, TUL, VM and JGM were involved in study design. EM, ZF, AGAG, RVF and JES were involved in data collection. LR, EM, ZF, TUL and JES were involved in data analysis. SM, RVF, AGAG, AM, JES, RR and VM were involved in data interpretation. RR and JGM provided research mentorship and funding. LR and EM wrote the first draft of the manuscript. All authors edited and reviewed the manuscript.

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Data sharing statement

All data is available upon request.

Declaration of Competing Interest

JGM received funding from the Kletjan Foundation, General Electric Foundation and from a Ronda Stryker and William Johnston personal foundation. None of the other authors have any conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eclinm.2020.100620.

Appendix

Modified SAT tool

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