A granular analysis of service delivery for surgical system strengthening: Application of the Lancet indicators for policy development in Colombia

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Summary

Background *The Lancet* Commission on Global Surgery (LCoGS) surgical indicators have given the surgical community metrics for objectively characterizing the disparity in access to surgical healthcare. However, aggregate national statistics lack sufficient specificity to inform strengthening plans at the community level. We performed a second-stage analysis of Colombian surgical system service delivery to inform the development of resource- and context-sensitive interventions to inform a revision of the Decennial Public Health Plan for access inequity resolution.

Methods Data from the year 2016 to inform total operative volume (TOV) and 30-day non-risk adjusted peri-operative mortality (POMR) were collected from the Colombian national health information system. TOV and POMR were sub-characterized by demographics, urgency, service line, disease pathology and facility location.

Findings In 2016, aggregate national mortality was 0·87%, while mortality attributable to elective and emergency surgery was 0·73% and 1·30%, respectively. The elderly experienced a 5·6-fold higher mortality, with 4·2% undergoing an operation within 30 days of dying. Individuals undergoing hepatobiliary, thoracic, cardiac, and neurosurgical operations experienced the highest mortality rates while obstetrics, general surgery, orthopaedics, and urology performed the largest procedure volume. Finally, analysis of operation and service line specific POMR reveals opportunities for improvement.

Interpretation This granular second-stage analysis provides actionable data which is fundamental to the development of resource and context-sensitive interventions to address gaps and inequities in surgical system service delivery. Furthermore, this analysis validates the modeling underlying development of the LCoGS indicators. These data will inform the assessment of implementation priorities and revision of the Colombian Decennial Public Health Plan.

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Keywords: Global surgery; Core surgical indicators; Total operative volume; Post-operative mortality rate; Global health; National surgical planning

Introduction

In 2015, the Lancet Commission on Global Surgery (LCoGS) estimated that at least 5 billion individuals lack access to surgical, obstetric, and anaesthesia services when needed.[1] Concerningly, the burden of cancer and injury-related disease is increasing steadily with low-to-middle-income countries (LMICs) disproportionately affected.[2−4] Recognizing the need for bidirectional

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Research in context

Evidence before this study

The present study was informed by relevant public health and global surgery literature, and global health organization position statements published over the last several years which have documented the current challenges in addressing the staggering disparity in access to surgical, obstetric, and anaesthesia (SAO) care when needed. In 2015, in addition to estimating that 5 billion people globally lack access to SAO care, *The Lancet* Commission on Global Surgery (LCoGS) introduced a core set of indicators for the performance of an objective and reproducible SAO system situation analysis. These indicators were selected to inform the strengthening of a surgical health care system by addressing infrastructure, service delivery, workforce, information management, finance, and governance needs (WHO health system building blocks). The goal of an indicator-based situation analysis is the development of a national surgical, obstetric, and anaesthesia plan (NSOAP) intended to close identified gaps in a coordinated, context-sensitive, and sustainable fashion. Since the publication of Global Surgery 2030, several nations have undertaken this important work. However, few nations have successfully leveraged these situation analyses to develop national surgical obstetric and anaesthesia plans. To date, reported examples have exclusively come from low-income countries reinforcing the importance of developing methods for achievement in middle- and upper-income countries. Troublingly, few funded intervention implementations predicated solely on an LCoGS indicator-based situation analysis have been documented. We propose that this is due to the need for a second-stage analysis of an indicator-based assessment to provide granular, actionable data to inform the development and implementation of cultural, context, and resource-sensitive sustainable funded policy initiatives.

Added value of this study

We believe this work adds value to the existing evidence for the following reasons. First, the present analysis demonstrates the intimate linkage between LCoGS indicators, such as specialist provider density (indicator two) and operative volume (indicator three), at the service line level. This is essential to empower professional SAO societies, which possess intimate knowledge of the necessary steps to promote durable workforce expansion, to develop and implement actionable interventions to strengthen service delivery in coordination with ministries of health. Second, this analysis provides validation of the models used to derive LCoGS core surgical indicators one through four by confirming their proposed interdependence using real-world data. Third, and perhaps most importantly, the present analysis demonstrates a systematic approach to extend and build upon a core indicator-based situation analysis to provide a granular assessment of SAO system gap to inform specific, measurable, attainable, relevant, time-bound, and equitable disparity resolution.

Implications of all the available evidence

Despite World Health Organization advocacy and recognized empiric value, a paucity of funded, LCoGS indicator-based, NSOAP driven interventions threatens a much-needed broader adoption among low-, middle- and upper-income countries. As Colombia works to realize a universal healthcare system, this analysis will directly inform the strengthening of existing programs such as *Rutas Integrales de Atención en Salud* (Integrated Routes of Health Care, RIAS). RIAS is designed for the provision of integrated care by establishing baseline health needs of individuals and communities to enable early diagnosis and treatment of disease, rehabilitation, and palliative care. Furthermore, vital stakeholder engagement has been enhanced with the provision of specific actionable data. Finally, SAO system strengthening is now poised for inaugural inclusion in the Decennial Public Health Plan informed by actionable data. As an upper-middle-income country, the Colombian experience may serve as an example of how an augmented LCoGS core indicator-based situation analysis can inform SAO system strengthening within an existing complex healthcare infrastructure.

partnership and global mobilization of resources, the World Health Organization (WHO) advocated for and incorporated mechanisms for reporting national emergency and essential Surgical, Anaesthesia, and Obstetric (SAO) care strengthening efforts.[5,6] This was based on the development by the LCoGS of a framework through which stakeholders can begin to perform a situation analysis of the surgical healthcare system to objectively identify gaps and barriers to care.[1] The LCoGS proposed six core surgical indicators to characterize SAO healthcare access, service delivery and cost protection (Table 1). These indicators were selected to inform the strengthening of a surgical health care system in a systematic and reproducible approach by addressing infrastructure, service delivery, workforce, information management, finance, and governance needs (WHO health system building blocks).[7−9] The goal of an indicator-based situation analysis is the development of a National Surgical, Obstetric, and Anaesthesia plan (NSOAP) intended to close identified gaps in a coordinated, context-sensitive and sustainable fashion.

Since the publication of Global Surgery 2030, several nations have undertaken this important work.[10−14] From these experiences, challenges to performing a complete non-modelled LCoGS based indicator analysis have been recognized such as limited data availability and accessibility, as well as insufficient workforce to pursue data aggregation, analysis, and reporting. Furthermore, little has been documented with respect to efforts or successes in incorporating the LCoGS surgical

System Category		Indicator Definition	Target Goal
PREPAREDNESS	1	Proportion of the population that can access, within 2 h, a facility that can perform the Bellwether procedures (laparotomy, caesarian section, open fracture intervention)	A minimum of 80% coverage of essential surgical and anesthesia services per country by 2030
	2	Number of specialist surgical, anesthetic, and obstetric physicians who are working per 100,000 population	100% of countries with at least 20 surgical, anesthesia and obstetric physicians per 100,000 population by 2030
DELIVERY	3	Procedures done in an operating theatre, per 100,000 population per year	80% of countries by 2020, 100% of countries by 2030 tracking volume; A minimum of 5,000 procedures per 100,000 population by 2030
	4	All-cause death rate before discharge in patients who have had a procedure in an operating theatre, divided by the total number of procedures	80% of countries by 2020 and 100% of countries by 2030 tracking POMR: In 2020, evaluate global data and set national targets for 2030
IMPACT	5	Proportion of households protected against impoverishment from direct out-of-pocket payments for surgical and anesthesia care	100% protection against impoverishment from out-of-pocket payments for surgical and anesthesia care by 2030
	6	Proportion of households protected against catastrophic expenditure from direct out-of-pocket payments for surgical and anesthesia care	100% protection against catastrophic expenditure from out of pocket payments for surgical and anesthesia care by 2030

***Table 1*: The Lancet Commission on global surgery surgical indicators definitions and targets.**

indicators into national dashboard metrics for ongoing monitoring and evaluation.[12] Even fewer nations have successfully leveraged these situation analyses to develop national surgical obstetric, and anaesthesia plans. To date, reported examples have exclusively come from low-income countries (LICs) reinforcing the importance of developing methods for successful achievement in middle and high-income countries.[8] Multiple barriers hamper the transition from baseline situation analysis to comprehensive plan development. These include difficulty in articulating actionable gap resolution measures, competing stakeholder priorities, insufficient workforce and funding for the development and implementation of NSOAPs.

Underlying many of the barriers to developing an NSOAP is the need for a more granular characterization of a nation's SAO healthcare system, and contextualization to inform policy makers' value-based decision making concerning the distribution of funding. Objective data are needed for a responsible and egalitarian distribution of funding as nations work to ensure equitable access and the development of universal health care systems. For example, LCoGS indicator 1 defines access to a facility capable of providing emergency and essential SAO care based on a travel time metric. However, without context with regard to barriers to access within 2 h as defined, stakeholder engagement and subsequent identification of specific, measurable, attainable, relevant, and time-bound (SMART) solutions are difficult.[15] In the present analogy, access may be limited by motor vehicle or fuel availability, roadway conditions, insurance coverage for the nearest facility, or safety concerns in areas of conflict; intervention design is dependent on the precise description of context and aetiology. Although efforts have been made to refine the definition for indicator 1 for more precise barrier identification, additional work is needed across the indicators as ministries of health, stakeholders, and academic global surgeons evolve the science of surgical system situation analysis in a manner that does not unduly burden nations with limited resources.[12,16]

Colombia is a Latin American nation of approximately 50 million lives with a constitutionally mandated national health insurance regime.[17] It is the first upper-middle-income country to complete a non-modelled surgical system situation analysis to support the expansion of the national health system plan (Decennial Plan) scope of advocacy and action.[12,18] While this ecologic study provided an informative national characterization at the municipal level, it lacks sufficient granularity to answer questions at the policy level concerning SMART interventions (goals) that can be proposed in the Decennial Plan. This is consistent with the observation that few interventions have been implemented solely based on an LCoGS indicator based situation analysis alone.[19] Therefore, in partnership with the Colombian Ministry of Health, we undertook a second stage analysis of the Colombian SAO system's service delivery capacity as defined by LCoGS indicators three and four (total operative volume, and post-operative mortality, respectively) to enable identification of granular and actionable goals. Total operative volume (TOV) was sub-characterized along with several domains including patient demographics, socioeconomic status (SES), geographic location, disease process and service line. This was further contextualized with 30-day non-risk adjusted post-operative mortality data (POMR) to inform discussions about quality and value. Finally, these system performance characteristics were compared to global surgical data to add further context as stakeholders begin to prioritize objectives and key results for the next decade.

Methods

Data sources

The primary data sources used for an LCoGS indicator three and four sub-analysis were the Colombian national healthcare information system *Sistema Integral de Información de la Protección Social* (SISPRO) which was previously described by Hanna et al. (*Supplementary Appendix* 2).[12] SISPRO aggregates administrative, claims, and health services data and includes *Los Registros Individuales de Prestación de Servicios de Salud* (RIPS), which is a registry of Colombia's healthcare services used for regulation of the health system.

Total operative volume

RIPS was queried to determine total operative volume for the year 2016 to correspond with the most recently available national peri-operative mortality data.[12] The RIPS database contains operative procedure data without procedure location information (i.e. operating room vs. other). Therefore, using a previously described Unique Classification of Health Procedure (*Clasificación Única de Procedimientos en Salud,* CUPS) code set, procedures most likely to be performed in an operating theatre were identified.[12] This CUPS list was used to filter all billed procedure codes in RIPS. Since RIPS output does not include unique patient identifiers due to privacy concerns, CUPS codes associated with individual operative episodes were linked by demographic identifiers including age, sex, insurance status, facility code, diagnostic code, week and month of procedure. For operative episodes with multiple procedure codes, the primary operation was defined using the American College of Surgeons National Surgical Quality Improvement Program methodology of using the procedure code associated with the largest relative value unit. This was performed using the *Acuerdo No. 256 DE 2.001* rates manual augmented by the internal rates manual of a quaternary care centre in Bogotá, Colombia. Finally, the elderly cohort was defined as being aged 65 or older at the time of operation.

Service line and urgency determination

To determine surgical service line operative performance, the CUPS code set was further categorized by surgical specialty by a Colombian- and US-based surgeon-researcher, both board-certified in the clinical practice of emergency and essential surgery. This categorization was made with specific attention to allow for the recognisation of nuances in procedure performance unique to the Colombian context. As urgency status is not recorded in RIPS, a US-based state Medicaid categorization of International Classification of Diseases-10 (ICD-10) diagnosis codes was used to determine the emergency status for each operative encounter.[20] The elective to emergency (Ee) ratio was calculated as described by Prin and colleagues.[21]

Post-operative mortality

Due to database limitations, in-hospital mortality could not be specified. Given that there is an acceptable correlation between in-hospital mortality and 30-day mortality, we elected to define perioperative mortality as all-cause non-risk-adjusted mortality occurring within 30-days inside or outside a hospital for all patients who underwent a procedure in an operating room.[1,22] To calculate this, RIPS was queried for all surgical procedures (certain and likely)[12] in 2016 and this output was cross-referenced with data from the DANE (*Department Administrativo Nacional de Estadística*) mortality database[23] to determine if a death was preceded by a surgical procedure. Duplicate entries were then filtered, and the data was limited to deaths within 30 days of a procedure. The total number of post-operative deaths which occurred within 30 days of a procedure was then divided by the total operative volume to calculate the all-cause, non-risk-adjusted post-operative death rate.

Travel to care analysis

The geographic centre point of each municipality was determined using ArcGIS Online, after which an array was built of each possible municipality pair and the straight-line distance between the two respective centre points. This array was then used to calculate a straight-line distance between the origin (patient home municipality) and destination (hospital municipality) information obtained from RIPS for each operative episode. This was used as a surrogate for travel distance. Therefore, if the origin and destination were the same, the calculated distance would be zero. These distance estimates were then used to determine service line specific travel patterns and relationship to SES using insurance regime enrollment as a proxy as previously described.[12] We used subsidized regime enrollment as a surrogate marker of lower socioeconomic status because eligibility is determined by the System for Selecting Beneficiaries of Social Spending which relies on proxy means testing for income and poverty.[24]

Statistical analysis

The student *t*-test was performed to assess statistical significance at a p-value $< 0{\cdot}05$ when the mean of two populations was compared while a Chi-square test was used to compare categorical values. Pearson's correlation coefficient was used to compare continuous variables when needed.

Role of the funding source

There are no funding sources to report for this study.

Results

Aggregate TOV and POMR characteristics

In 2016, 1,190,302 individual operative episodes were completed, for a TOV of 2450 per 100,000 population, of which 9·3% were recorded without a diagnosis code. Of the 1,044,923 episodes with a diagnostic code, 74·8% were classified as elective and 25·2% were classified as emergency operations with an observed POMR of 0·73% and 1·30%, respectively ($p < 0{\cdot}00001$). The calculated emergency to elective surgery ratio is 33·6. Of the total operative episodes, 81% and 19% were performed in the young vs elderly, respectively. Aggregate POMR was 0·87%, with a 5·6-fold difference between the young vs elderly (0·47% vs 2·61%, respectively, $p < 0{\cdot}00001$, Table 2). Of all operations performed in the elderly, approximately 4·2% were performed within 30 days of dying (Table 3). Furthermore, 10·1% and 11·6% of elders who underwent an operation within 30 days of dying underwent a concomitant tracheostomy or gastrostomy placement, respectively. When the insurance regime was examined, a statistically significant difference was observed between the proportion of young vs elderly patients dependent on the subsidized insurance regime (49% vs 54%, $p < 0{\cdot}00001$, Table 4).

Service line specific performance

Individual surgical service line performance for TOV and POMR were calculated as well as proportion enrollment in the subsidized insurance regime (Table 5). Obstetrics and gynaecology, general surgery, orthopaedics, ophthalmology, and urology had the highest observed TOV while thoracic surgery, hepatobiliary, colorectal, cardiac, and general surgery had the highest observed POMR (Table 6).

	Number	Proportion
Elective Cases	890687	74·8%
Mortality	6469	0·73%
Emergent Cases	299615	25·2%
Mortality	3888	1·30%
Young (age <65) Cases	970960	81%
Mortality	4533	0·47%
Elderly (age >64) Cases	223195	19%
Mortality	5824	2·61%
Total Operative Episodes	1175854	
Aggregate POMR	0·87%	

***Table 2*: Baseline TOV and POMR statistics.**

Age Group	Proportion
65–84	4·98%
85–99	2·85%
>99	1·57%
Aggregate	4·23%

***Table 3*: Geriatric mortality distribution.**

	Age <65	Age > 64
Contributory	38%	37%
Subsidized	49%	54%
Other	13%	9%

***Table 4*: Insurance regime utilization by age group.**

Benchmark operation global comparison

Colombian surgical system POMR was compared to selected benchmark procedures previously described (Table 7).[25,26] Notable outliers with higher mortality include cardiac valve procedures, esophagectomy, pancreatic resection, liver resection, colorectal resection, pneumonectomy, and open abdominal aortic repair. In contrast, mortality associated with exploratory laparotomy and bowel obstruction was lower (Table 7).

Multi-specialty care service line mortality burden

Multi-specialty care service line specific POMR was calculated for trauma, surgical oncology, pediatric surgery, and emergency general surgery. For trauma care, the highest mortality was observed for neurosurgical disease and the lowest in injuries requiring orthopaedic or plastic and reconstructive intervention in adults and children (Table 8). For surgical oncology, of the top five most common cancer diagnoses, pulmonary, gastric, and colon cancer carried the highest mortality rates (Table 9). The lowest volume disease pathologies (vascular, hepatobiliary, cardiac, neurosurgical) were associated with the highest mortality rates in the pediatric surgery population (Table 10). Finally, although the majority of emergency general surgery operations performed are attributable to appendicitis and cholecystitis resulting in a low overall POMR, colectomy, small bowel resection, and laparotomy are associated with particularly high mortality in adults (Table 11). The rate of three commonly performed general surgical procedures, appendectomy, cholecystectomy, and inguinal herniorrhaphy, were found to be 46·7, 46·7, and 34·7 per 100,000 population, respectively.

Service line and socioeconomic status specific travel burden

When distance travelled to access care was evaluated, calculated as the ratio of the proportion of all distance travelled in kilometres to the proportion of TOV, access to the most specialized service lines (hepatobiliary,

Service Line	Cases / 100,000 population	% Total	Age < 65		Age > 64	
			Proportion	% Subsidized	Proportion	% Subsidized
Neurosurgery	62	2·56%	80·15%	55·82%	19·85%	53·21%*
Head & Neck	24	1·00%	86·96%	45·74%	13·04%	43·29%
ENT	182	7·53%	85·42%	45·96%	14·58%	41·49%*
General Surgery	451	18·64%	83·60%	56·18%	16·40%	60·60%*
Cardiac Surgery	37	1·53%	46·25%	49·03%	53·75%	48·86%
Thoracic	52	2·16%	78·21%	64·00%	21·79%	62·76%
Breast	26	1·08%	89·07%	53·29%	10·93%	44·16%*
Colorectal	30	1·23%	76·56%	47·15%	23·44%	50·18%*
Hepatobiliary	7	0·29%	71·05%	52·43%	28·95%	48·56%*
ObGyn	504	20·82%	97·85%	59·92%	2·15%	52·97%*
Urology	245	10·11%	63·89%	47·45%	36·11%	60·99%*
Orthopedics	343	14·18%	84·96%	56·32%	15·04%	60·41%*
Vascular	50	2·08%	77·03%	58·37%	22·97%	63·50%*
Pediatric Surgery	1	0·05%	97·45%	61·78%	2·55%	85·71%
Ophthalmology	245	10·12%	55·93%	59·32%	44·07%	64·63%*
Plastic and Reconstructive	142	5·86%	84·88%	56·33%	15·12%	63·16%*
Other	18	0·76%	77·12%	43·21%	22·88%	45·10%

***Table 5*: Service line productivity and insurance enrollment.**

* denotes $p < 0.05$ comparing subsidized regime utilization by age and service line.

cardiac, upper GI, vascular, neurosurgery, thoracic) was associated with the largest ratios (Table 12). Municipalities without 2 h access to a bellwether capable facility were associated with a mean travel to care distance of >180 km (r_s=0·20, $p < 0{\cdot}001$). This is visually reflected in the geographic information system mapping of distance travelled to care where residents of municipalities without a bellwether capable facility travelled the largest distances (Figure 1). Additionally, across all surgical service lines, the travel burden for Colombian citizens of lower SES (subsidized vs contributory regimes) was found to be significantly higher (Table 13).

Discussion

Since the initial description in 2015 of the LCoGS core surgical indicators, several nations have completed baseline surgical system situation analyses employing

Service Line	POMR	Age <65	Age >64	Geriatric:Young Mortality Ratio
Neurosurgery	3·52%	2·66%	7·01%	2·6
Head & Neck	0·31%	0·25%	0·72%	2·8
ENT	0·23%	0·12%	0·90%	7·7
General Surgery	1·62%	0·78%	5·91%	7·6
Cardiac Surgery	2·71%	2·97%	2·49%	0·8
Thoracic	6·42%	4·13%	14·63%	3·5
Breast	0·22%	0·14%	0·87%	6·1
Colorectal	3·48%	1·84%	8·83%	4·8
Hepatobiliary	6·34%	5·36%	8·76%	1·6
ObGyn	0·05%	0·04%	0·55%	15·6
Urology	0·50%	0·21%	1·01%	4·8
Orthopedics	0·55%	0·17%	2·65%	15·3
Vascular	1·87%	1·15%	4·28%	3·7
Pediatric Surgery	0·00%	0·00%	0·00%	N/A
Ophthalmology	0·06%	0·04%	0·10%	2·4
Plastic and Reconstructive	0·65%	0·31%	2·54%	8·3
Other	0·15%	0·12%	0·24%	2·1

***Table 6*: Service line specific mortality.**

Primary Procedure Category	Mortality	Semel - USA 2006	Ng-Kamstra - pooled 2018
Aggregate Rate	0·87%	1·68%	
Valves - All Cardiac Procedures	10·09%		4·17%
Repair Congenital Heart Disease	8·22%		14·94%
Thoracic Aortic Reconstruction	8·18%		9·5%
Coronary Artery Bypass	7·05%	2·49%	4·38%
Implant of pulsation balloon	27·14%	25·95%	
Tracheostomy	25·78%	22·51%	
Gastrostomy	17·51%		
PEG	15·34%	6·19%	
Peptic Ulcer Procedures	12·86%		
Small Bowel Resection	12·55%	10·38%	
Gastric Procedures	8·24%	6·13%	
Appendectomy	0·26%	0·01%	
Cholecystectomy	0·61%		0%
Esophagectomy	11·88%	4·77%	
Exploratory Laparotomy	6·36%	14·38%	12·53%
Bowel Obstruction	9·84%		12·32%
Inguinal Hernia	0·15%		0·38%
Pancreatic Resection	13·64%	4·1%	
Whipple	21·33%		2·94%
Liver Resection	9·47%		1·04%
Colectomy	13·70%		
Rectal Resection	3·89%		0·07%
Colorectal Resection	12·68%	4·4%	2·83%
Uterine Packing - Post-partum Hemorrhage	5·85%		
Hysterectomy	0·22%		
Cesarean section	0·03%		0·05%
Intracranial Embolectomy	14·44%		
Decompression - SDH/EDH/Craniotomy	8·12%		
Intracranial Tumor Resection	5·44%		1·29%
Spine Decompression	1.67%		0.77%
Correction of craniosynostosis	1.36%		
Fracture - Closed Reduction	0.20%		
Fracture - Open Reduction	0.73%	2.06%	
Femur Fracture - Open Reduction	3.92%		
Lobectomy/Pneumonectomy	8.33%	3.08%	1.3%
Flexible Bronchoscopy with Bx	6.95%	4.78%	
Nephrectomy	4.14%	1.32%	
Cystectomy	4.44%	1.85%	
Open Abdominal Aortic Repair	26.51%	8.62%	
Pediatrics - all cases age <18	0.31%		6.16%

***Table 7*: Benchmark procedure comparison.**

various methodologies.[12−14,27−29] However, the identification of disparities or gaps in access, service delivery, and cost protection at a national level has been insufficient to inform actionable SMART goals that stakeholders can articulate to enable policymakers to make informed funding decisions. This concern was recently explored by Binda et al. who performed an analysis of interventions informed by an LCoGS core indicator analysis and found few documented examples.[19] Furthermore, in our experience, we have encountered scepticism among stakeholders at various levels with respect to how effective the modelled LCoGS indicators can be with respect to informing policy and financial decisions. Therefore, to enable and inform incorporation of SAO health system strengthening in the revision of the Colombian Decennial Public Health Plan currently underway, we have expanded the concept of surgical system situation analysis by undertaking a second stage exploration of SAO service delivery. This was done by characterizing TOV and POMR by age group,

	Adult		Pediatric	
	% Total	Mortality	% Total	Mortality
Orthopedics	67·45%	0·55%	74·92%	0·01%
Plastic and Reconstructive	15·90%	0·22%	15·09%	0·00%
Thoracic	5·09%	2·08%	3·47%	0·55%
General Surgery	3·12%	3·10%	1·64%	0·23%
Neurosurgery	2·14%	8·06%	1·26%	2·72%
All Other	6·30%	2·23%	3·62%	0·84%

***Table 8*: Multi-specialty care: trauma service line mortality burden.**

	TOV	Mortality
Cholecystectomy	44·40%	0·61%
Appendectomy	38·87%	0·26%
Lysis of Peritoneal Adhesions	14·25%	1·80%
Laparotomy	1·03%	9·33%
Excision of Colon	0·73%	25·00%
Peptic Ulcer Disease	0·37%	12·86%
Excision Small Intestine	0·36%	24·05%
Total		1·04%

***Table 11*: Multi-specialty care: emergency general surgery service line mortality burden.**

	% Total	Mortality
Breast	15·17%	1.54%
Prostate	6·39%	1.53%
Gastric	3·44%	10.60%
Colon	3·17%	8.19%
Lung	1·61%	15.55%
All Oncologic Surgery		3·28%

***Table 9*: Multi-specialty care: surgical oncology service line mortality burden.**

urgency status, service line, and procedure informed by associated travel distance and patterns as well as insurance status and pathology.

LCoGS indicator three (total operative volume) can be expanded upon through a second stage analysis using the level of operative urgency. Emergent provision of care, and in particular emergency operations, are associated with increased patient morbidity, mortality, cost, and provider burnout.[30–32] Furthermore, the ratio of emergency to elective surgical volume has been demonstrated to be reflective of the availability of surgical services.[21] This allows validating gaps identified in system access (LCoGS indicators one and two) with actual procedure utilization. A calculated Colombian emergency to elective surgery ratio (Ee) of 33·6 per 100 elective procedures, compared to a median value of 5·5 for European countries and 9·4 for the United States, is consistent with the access disparity identified for 2 h geographic access and SAO provider density which disproportionately affects those of lower socioeconomic status.[12,21] In comparison, Brazil has reported operative

	Mortality
Neurosurgery	1·44%
Head & Neck	0·07%
ENT	0·04%
General Surgery	0·42%
Cardiac	4·02%
Thoracic	1·60%
Breast	0·00%
Upper GI	1·58%
Lower GI	1·82%
Hepatobiliary	3·96%
ObGyn	0·03%
Urology	0·04%
Orthopedics	0·03%
Vascular	5·18%
Pediatric Surgery	0·00%
Ophthalmology	0·09%
Plastic and Reconstructive	0·13%
Other	0·41%
Total	0·31%

***Table 10*: Multi-specialty care: pediatric surgery service line mortality burden.**

	Proportion of Km Traveled to TOV	Municipalities without a recorded case	Population without a recorded case
Neurosurgery	1·26	224	1,566,672
Head & Neck	1·00	380	3,483,504
ENT	0·82	104	659,301
General Surgery	0·89	45	205,787
Cardiac	1·64	297	2,897,482
Thoracic	1·22	206	1,595,690
Breast	0·88	389	3,559,412
Upper GI	1·37	540	6,946,568
Lower GI	0·96	359	3,415,784
Hepatobiliary	1·78	658	8,836,512
ObGyn	0·90	55	268,305
Urology	0·90	98	603,984
Orthopedics	1·09	33	109,198
Vascular	1·27	269	2,403,064
Pediatric	1·14	947	16,392,070
Ophthalmology	1·04	83	525,305
Plastic and Reconstructive	1·17	109	594,454
others	0·83	588	8,022,328

***Table 12*: Service line specific travel burden.**

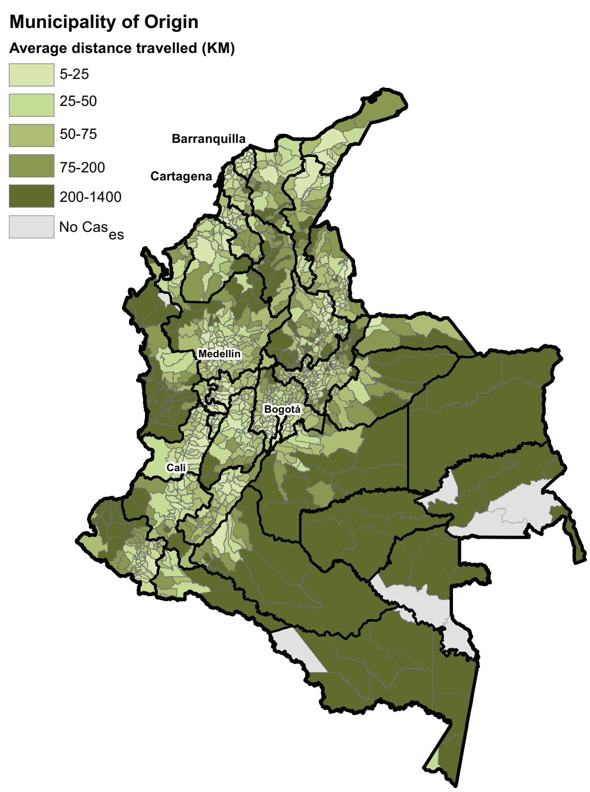

Figure 1. Geospatial representation of the average distance travelled to access SAO healthcare by municipality of origin.

volume data from which an Ee ratio of 139·7 can be calculated.[33] The relatively high burden of emergency surgical care in Colombia suggests an opportunity to explore interventions to expand access and service delivery as it pertains to increased elective operative capacity. In this way, delays in care resulting in emergencies may be reduced resulting in decreased morbidity and mortality while decreasing costs and increasing

	Contributory Regime (km)*	Subsidized Regime (km)*	Subsidized: Contributory Travel Ratio	*p*-value
Neurosurgery	22·1	45·1	2·0	<0·00001
Head and Neck	19·9	37·3	1·9	<0·00001
ENT	15·3	30·1	2·0	<0·00001
General Surgery	16·9	29·7	1·8	<0·00001
Cardiac Surgery	25·1	64·5	2·6	<0·00001
Thoracic	23·0	41·2	1·8	<0·00001
Breast	17·4	29·6	1·7	<0·00001
Colorectal	19·8	38·4	1·9	<0·00001
Hepatobiliary	36·0	59·9	1·7	<0·00001
ObGyn	17·3	29·3	1·7	<0·00001
Urology	16·6	29·7	1·8	<0·00001
Orthopedics	20·9	34·9	1·7	<0·00001
Vascular	18·4	36·6	2·0	<0·00001
Pediatric Surgery	27·3	31·0	1·1	<0·00001
Ophthalmology	20·0	33·4	1·7	<0·00001
Plastic and Reconstructive	21·7	39·7	1·8	<0·00001
Other	15·5	27·9	1·8	<0·00001

***Table 13*: Service line specific travel burden by socioeconomic status.**

* mean distance travelled to care.

the value of care provided. Furthermore, by unburdening clinicians with the volume of emergency cases, retention, and growth of SAO provider density may be positively impacted.

Similarly, understanding the impact of SAO service provision in the geriatric population is a critical component to providing high-value care that is just, beneficent, and nonmaleficence.[34,35] The observed mortality rate of 2·6% in the elderly population is similar to that observed in New Zealand (1·8% from 2005 to 2017) and from a US single-centre study (3·8% in 2006).[36,37] The proportion of decedents in 2016 that underwent a surgical procedure within 30-days of dying is 4·2%, which is markedly lower than the US experience (18·3% in the year 2008).[35] Of those elders who died within 30 days of an operation, approximately 10% underwent a tracheostomy or gastrostomy tube placement. Comparison of these data across nations is confounded by varying societal, cultural, and SAO provider beliefs, values, and attitudes, as well as access and service delivery disparities. Nonetheless, it is encouraging to note the relatively low proportion of Colombian elders undergoing a non-therapeutic operation in the final days of life. Opportunities may exist for enhancing end of life care by exploring ways in which placement of tracheostomies and durable enteral access may be reduced. Finally, through the subsidized insurance regime the government endeavours to ensure equitable healthcare access to all Colombians. Across the globe, the elderly are more likely to live below the poverty line, therefore their ability to access surgical healthcare when needed is generally decreased.[38] One dimension of the value of the subsidized regime as a safety net to access is reflected in the proportion of Colombian elders, which is significantly higher than in those under the age of 65, dependent on accessing SAO care through this regime.

A disease-specific second stage analysis of TOV linked with specialist-surgeon density provides granular data to inform workforce strengthening initiatives. Observed congruence between indicators can further validate an indicator-based SAO situation analysis and promote acceptance and incorporation into national health system plan development, implementation, and evaluation. TOV is modelled on crude estimates of surgical need informed by the global burden of disease.[1] The observed Colombian TOV, which is approximately 50% of target, is consistent with observed insufficient disease-specific operative volume. For example, the global appendectomy rate is estimated at 100 per 100,000 population.[39] In the present analysis, the mean appendectomy rate in Colombia is 46·7/100,000. This is consistent with an insufficient TOV and observed high age-standardized appendicitis DALY rates in Colombia.[40] Similarly, the observed rate of cholecystectomy of 46·7/100,000 population is short of that observed in Western nations by nearly 6-fold.[41] Finally, the observed rate for inguinal herniorrhaphy of 34·7/100,000 population is also well short of that observed in Western nations by nearly 4·5 to 8-fold.[42,43] This pattern is commensurate with the observed low density of Colombian general surgeons (1 per 100,000 population) which is nearly 6-fold lower than the most recent US estimate, and the absence of a registered specialist capable of providing general surgical services in 96% of Colombian municipalities.[12,44] Although operative volume capacity is not solely predicated on specialist SAO provider density, these data can inform individual SAO professional society workforce strengthening initiatives by targeting specific specialists and regions as one dimension of multidimensional strengthening efforts informed by the WHO health system building blocks.

Complementary to a second-stage service delivery analysis is the opportunity for inter-national benchmarking. While comparison of non-risk adjusted national POMR with the global experience should be undertaken with caution, the exercise can still inform SAO service line specific quality improvement goals and may facilitate sharing and adoption of successful intervention campaigns.[1,45] An example of this is the recently described "Essential Quality Improvement Program" designed to build a culture of safety with emphasis on achievable quality metrics in less resource-rich settings.[46] Similarly, lessons learned from the development of comprehensive multi-specialty care programs may also guide local resource development and organization. To support these efforts, characterization of individual service line specific contributions to multi-specialty care is critical in the design of context-sensitive comprehensive care delivery programs. These data provide a nuanced understanding of multi-specialty service line performance to inform policy interventions for barrier resolution.

We identified an increased mean travel distance for SAO care and specialty care in municipalities that were predicted to face an access disparity based on our previous LCoGS indicator one based analysis.[12] The LCoGS definition for indicator one is modelled on the optimal time to reach a bellwether capable facility for an abdominal or obstetric emergency.[1] To our knowledge, the present analysis is the first to validate the utility of bellwether based access modelling for predicting real-world SAO service access patterns informed by SES. Using cesarean section (which represents 7·3% of Colombian TOV) as a case for procedure specific analysis, it is noteworthy that it is the leading indication for travel >180 km due to insufficient local resources. In addition to exploring initiatives to strengthen local resources, a comprehensive understanding of the impact of this disparity, the clinical outcome for mother and child, maternal cost and societal cost impact should be explored. The value of extending a national service delivery characterization with service and operation-specific stepwise analysis is revealed by this granular delineation of disparities which can inform articulation of SMART interventions.

Revision of the Colombian Decennial Public Health Plan is a democratic consultative process designed to engage a multi-disciplinary and multi-sectoral stakeholdership for evaluation of the current state of the healthcare system, and goal setting for the next decade. SAO specific service line performance data such as productivity and mortality are essential for actionable gap identification and SMART resolution. Equally as important, these data also set the stage for strengthening existing national initiatives. For example, the *Rutas Integrales de Atención en Salud* (Integrated Routes of Health Care, *RIAS*) program is designed for the provision of integrated care by establishing baseline health needs of individuals and communities to enable early diagnosis and treatment of disease, rehabilitation, and palliative care.[47] Since concurrent delivery of medical and surgical services are required in the care of at least 34% of all cases of non-communicable disease, SAO health system strengthening is essential for the success of programs like *RIAS*.[48]

Study limitations

Although the Colombian health informatics system is a rich source of information, this analysis is subject to some limitations. First, to determine procedure urgency status in the absence of a specific flag in RIPS, we used a US-based Medicaid associated ICD10 code set. While the ICD10 code set is universal, country-specific nuances in diagnosis coding likely introduced an unmeasurable error in our analysis, though we believe that this is likely small. Furthermore, because 9·3% of the analyzed procedure records lacked a diagnosis, the urgency level of those operations could not be determined. Ultimately, while the emergency vs elective analysis is subject to an error rate of approximately 10%, this does not significantly change the conclusions drawn based on the relative difference between the Colombian Ee ratio in comparison to other countries. Second, the designation of which procedure in a multi-procedure operation is primary is not specified in RIPS. Therefore, we relied on the ACS-NSQIP methodology of using the procedure code with the highest associated relative value unit. It is conceivable that this may not accurately reflect the primary indication for the operation performed in all cases and therefore may have impacted our disease-specific volume and mortality estimates. Third, the accuracy of the data stored in RIPS was most recently assessed in 2013.[49] This analysis suggests a relatively low error rate with respect to data fidelity, though even small errors can be exponentially compounded when analyzing data sets of this size. Finally, concerning the travel to care analysis, due to database limitations, the address of origin could not be determined for use in travel distance calculations. Residents of rural areas face difficulties in accessing public roadways in addition to recognized public roadway underdevelopment and disrepair. Thus, estimated travel distances calculated using the geographic centre-point of each municipality may provide an incomplete assessment of the challenges faced by residents in reaching a healthcare facility when care is needed. Despite the errors introduced by these limitations, because of the remarkable congruence between indicators within this analysis, we believe that this analysis is sufficiently robust to inform the development of actionable gap resolution initiatives.

Conclusions

SAO system service delivery is described by LCoGS indicators three and four which quantify the total operative volume and 30-day non-risk adjusted post-operative mortality. SMART and equitable gap resolution require actionable data to inform a multi-disciplinary and trans-disciplinary engagement for the development of context and resource-sensitive SAO service delivery strengthening. Colombia has enhanced an initial SAO system situation analysis with a more precise second stage analysis of TOV and POMR. This analysis has yielded several critical findings to inform incorporation of SAO system strengthening in the Colombian Decennial Public Health Plan. The linkage between LCoGS indicators, such as specialist provider density (indicator two) and operative volume capacity (indicator three) is essential and empowers professional SAO societies that possess intimate knowledge of the necessary steps to promote durable workforce expansion. Furthermore, this analysis provides validation of the models used to derive LCoGS core surgical indicators one through four by demonstrating their inter-relatedness using real-world data. Finally, the present methodology demonstrates a systematic and reproducible approach to build upon a core indicator-based situation analysis to provide a granular assessment of the SAO system gap to inform SMART and equitable disparity resolution. We believe this will enhance global acceptance and promote the development and adoption of NSOAPs.

Contributors

Andres Fernando Gomez Samper and Gabriel E Herrera-Almario contributed equally to this paper.

Andres Fernando Gomez Samper verified the underlying data and substantially contributed to the conception and design of the study; acquisition, analysis and interpretation of the data, drafting of the manuscript.

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Vicente Gracias substantially contributed to the interpretation of the data, revision of the manuscript.

Joseph S Hanna verified the underlying data and substantially contributed to the conception and design of the study, acquisition, analysis and interpretation of the data, drafting of the manuscript.

Data sharing statement

Access to the data used in this manuscript will be considered case-by-case upon request to the corresponding author.

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Declaration of interests

AFGS has nothing to disclose; GEHA has nothing to disclose; DT has nothing to disclose; DB has nothing to disclose; LLC has nothing to disclose; RENR has nothing to disclose; RR has nothing to disclose; VG has nothing to disclose; JSH has nothing to disclose.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lana.2022.100217.

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