

Use of the six core surgical indicators from the *Lancet* Commission on Global Surgery in Colombia: a situational analysis



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Summary

Background Surgical, anaesthetic, and obstetric (SAO) health-care system strengthening is needed to address the emergency and essential surgical care that approximately 5 billion individuals lack globally. To our knowledge, a complete, non-modelled national situational analysis based on the *Lancet* Commission on Global Surgery surgical indicators has not been done. We aimed to undertake a complete situation analysis of SAO system preparedness, service delivery, and financial risk protection using the core surgical indicators proposed by the Commission in Colombia, an upper-middle-income country.

Methods Data to inform the six core surgical system indicators were abstracted from the Colombian national health information system and the most recent national health survey done in 2007. Geographical access to a Bellwether hospital (defined as a hospital capable of providing essential and emergency surgery) within 2 h was assessed by determining 2 h drive time boundaries around Bellwether facilities and the population within and outside these boundaries. Physical 2 h access to a Bellwether was determined by the presence of a motor vehicle suitable for individual transportation. The Department Administrativo Nacional de Estadística population projection for 2016 and 2018 was used to calculate the SAO provider density. Total operative volume was calculated for 2016 and expressed nationally per 100 000 population. The total number of postoperative deaths that occurred within 30 days of a procedure was divided by the total operative volume to calculate the all-cause, non-risk-adjusted postoperative mortality. The proportion of the population subject to impoverishing costs was calculated by subtracting the baseline number of impoverished individuals from those who fell below the poverty line once out-of-pocket payments were accounted for. Individuals who incurred out-of-pocket payments that were more than 10% of their annual household income were considered to have experienced catastrophic expenditure. Using GIS mapping, SAO system preparedness, service delivery, and cost protection were also contextualised by socioeconomic status.

Findings In 2016, at least 7·1 million people (15·1% of the population) in Colombia did not have geographical access to SAO services within a 2 h driving distance. SAO provider density falls short of the Commission's minimum target of 20 providers per 100 000 population, at an estimated density of 13·7 essential SAO health-care providers per 100 000 population in 2018. Lower socioeconomic status of a municipality, as indicated by proportion of people enrolled in the subsidised insurance regime, was associated with a smaller proportion of the population in the municipality being within 2 h of a Bellwether facility, and the most socioeconomically disadvantaged municipalities often had no SAO providers. Furthermore, Colombian providers appear to be working at or beyond capacity, doing 2690–3090 procedures per 100 000 population annually, but they have maintained a relatively low median postoperative mortality of 0·74% (IQR 0·48–0·84). Finally, out-of-pocket expenses for indirect health-care costs were a key barrier to accessing surgical care, prompting 3·1 million (6·4% of the population) individuals to become impoverished and 9·5 million (19·4% of the population) individuals to incur catastrophic expenditures in 2007.

Interpretation We did a non-modelled, indicator-based situation analysis of the Colombian SAO system, finding that it has not yet met, but is working towards achieving, the targets set by the *Lancet* Commission on Global Surgery. The observed interdependence of these indicators and correlation with socioeconomic status are consistent with well recognised factors and outcomes of social, health, and health-care inequity. The internal consistency observed in Colombia's situation analysis validates the use of the indicators and has now informed development of an early national SAO plan in Colombia, to set a data-informed stage for implementation and evaluation of timely, safe, and affordable SAO health care, within the National Public Health Decennial Plan, which is due in 2022.

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For a Spanish translation of the abstract see [Online](#) for appendix 1

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Introduction

Strengthening of the surgical, anaesthetic, and obstetric (SAO) health-care system is urgently needed to improve access to emergency and essential surgical care that an estimated 5 billion individuals globally lack, particularly in low-income and lower-middle-income countries.¹ To address this wide disparity in equitable access to surgical health care when needed, health system strengthening should be informed by a granular national situation analysis predicated on relevant social and economic health and health-care system metrics.² In the past 5 years, methods of situation analysis have evolved to incorporate assessment of a population's access to SAO health care by use of a system model of preparedness, service delivery, and cost protection.¹ To assess and

empirically contextualise these three system access nodes,³ the *Lancet* Commission on Global Surgery proposed six corresponding core surgical indicators: geographical access to a Bellwether hospital within 2 h, SAO provider density, total operative volume, in-hospital postoperative mortality, and impoverishing and catastrophic cost burden (table 1).¹ Adoption of these six indicators has facilitated a global discussion to operationalise nation-specific SAO health-care system strengthening.

Conceptualised to align with the Commission's core surgical indicators, the national surgical, obstetric, and anaesthesia plan (NSOAP) proposes a framework to iteratively integrate surgical system strengthening interventions into the continuum of WHO health

Research in context

Evidence before this study

Review of the global surgical literature published over the past decade and of position statements, policy, and associated data from global health organisations provided the evidence and foundation that informed our study. 5 billion people worldwide do not have access to timely, safe, and affordable surgical care when needed. This estimate was derived by modelling the global population's access to emergency and essential surgery in a stepwise analysis of surgical system access nodes. To address the global disparity in access, which is particularly pronounced when comparing high-income and low-income countries, a new context for surgical system analysis and strengthening was established in the landmark *Lancet* Commission on Global Surgery 2030. Initially proposed in 2015, the six core surgical indicators described were formulated to define, assess, and inform surgical system preparedness, service delivery, and cost protection. The publication of this Commission was accompanied by increased WHO advocacy and new policy development to prioritise surgery, anaesthetic, and obstetric (SAO) care. These indicators facilitate the objective identification of disparities for the development of a value and evidence-based national SAO plan to address gaps in the timeliness, quality, and affordability of SAO system care. Indicator collection efforts in sub-Saharan Africa and other regions have culminated in the creation of a national SAO plan. This achievement has, in part, been possible because of a paucity of facilities and providers, resulting in relatively small indicator datasets. Although this early success might suggest that the task of achieving a complete non-modelled, core surgical indicator situation analysis is simple, only modelled analyses have been done in upper-middle-income or middle-income countries. Furthermore, assessment of these indicators in socioeconomic and regional contexts has not been possible.

Added value of this study

To our knowledge, this report is the first to describe a complete, non-modelled, indicator-based situation analysis in an

upper-middle-income country, as proposed by the *Lancet* Commission on Global Surgery. In addition, this study is the first situation analysis to contextualise an SAO system, as described by the indicators, including its associations with socioeconomic status. We have also expanded the concept of 2 h access to a Bellwether facility (defined as a hospital capable of providing essential and emergency surgery), and we distinguish between geographical and physical access by integrating geographical distance with provider availability and transportation means. Finally, we report on several hypothesised associations between socioeconomic status and geographical disparities in accessing the SAO system.

Implications of all the available evidence

As the value of an evidence-based national SAO plan is increasingly recognised, the demand for accurate, high-quality, geographically detailed surgical system indicator data has also increased. In a unique first step, the Colombian Ministry of Health, in parallel with our acquisition and analysis of the indicators, initiated development of a national dashboard to host the six core indicators. The stated goal of establishing the dashboard is to provide a fully transparent interface that all health system stakeholders can access in real time to support SAO system gap analysis. Furthermore, the Ministry of Health has developed and implemented two new programmes (the Territorial Comprehensive Action Model and Immediate Action Program for Hospitals) designed to address gaps in part identified through surgical system indicator data. These coordinated government efforts have laid the foundation for the integration of SAO system strengthening into the next revision of the Colombian Public Health Decennial Plan, which is due to be completed in 2022. The results of this inaugural integration of a national SAO plan within the larger health-care system strengthening framework is anticipated to bring Colombia closer to realising a universal health-care system.

	Definition	Goal
Preparedness		
Geographical access to a Bellwether hospital within 2 h	Proportion of the population who can access, within 2 h, a facility that can provide the Bellwether procedures (ie, laparotomy, caesarean section, or open-fracture treatment)	A minimum of 80% coverage of essential surgical and anaesthesia services per country by 2030
Surgical, anaesthetic, and obstetric provider density	Number of specialist surgical, anaesthetic, and obstetric physicians who are working per 100 000 population	100% of countries with at least 20 surgical, anaesthesia, and obstetric physicians per 100 000 population by 2030
Delivery		
Total operative volume	Procedures done in an operating theatre, per 100 000 population per year	80% of countries by 2020 and 100% of countries by 2030 tracking volume; a minimum of 5000 procedures per 100 000 population by 2030
In-hospital postoperative mortality	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 postoperative mortality; in 2020, evaluate global data and set national targets for 2030
Impact		
Impoverishing cost burden	Proportion of households protected against impoverishment from direct out-of-pocket payments for surgical and anaesthesia care	100% protection against impoverishment from out-of-pocket payments for surgical and anaesthesia care by 2030
Catastrophic cost burden	Proportion of households protected against catastrophic expenditure from direct out-of-pocket payments for surgical and anaesthesia care	100% protection against catastrophic expenditure from out of pocket payments for surgical and anaesthesia care by 2030

Adapted from Meara and colleagues.¹

Table 1: Lancet Commission on Global Surgery surgical indicators

system building blocks: governance, finance, infrastructure, information management, workforce, and service delivery.^{4,5} The national SAO plan framework has been designed to achieve SAO health-care system strengthening by developing solutions to barriers identified by a national SAO system situation analysis. The proposed outcome is the organisation of ministries of health and multiprofessional, multisectoral, and multidisciplinary stakeholders around WHO health system building blocks for the development of the NSOAP, through a coordination of goals, objectives, and key results, driven by the indicators identified by the Commission. Since 2015, NSOAP development, informed by the Commission's indicators, has been achieved in several low-income countries.^{6,7} Early efforts to objectively monitor and evaluate the implementation of specific components of these national SAO plans are currently underway.^{7,8}

Colombia is an upper-middle-income unitary republic⁹ with an approximate population of 48.7 million people, of whom 28% live below the national poverty line (appendix 2 p 1). Colombia is ideally positioned to undertake SAO health-care system strengthening, having instituted several health-care interventions towards universal health coverage. First, Colombia's recognition of health as a fundamental right was operationalised in 1993 through Law 100, which established a universal health insurance plan.^{9,10} Second, the health system continues to undergo iterative improvement, as exemplified by the launch of the Territorial Comprehensive Action Model and Immediate Action Program for Hospitals in 2018. The Territorial Comprehensive Action Model is designed to improve population health and health system sustainability, whereas the Immediate Action Program for Hospitals has been established to

provide immediate assistance to address infrastructure, quality, workforce, and institutional factors impeding service delivery. Third, the health-care system undergoes an objective evaluation and iterative strengthening process every 10 years, which is articulated in the Public Health Decennial Plan.¹¹ These efforts are underway despite a paucity of data to determine the current state of access to timely, quality, and affordable emergency and essential SAO health care. An absence of a specific SAO system assessment has been noted in more than 60% of national health system plans reviewed in a comparative analysis in 2019.¹² An indicator-based SAO health-care system situation analysis is anticipated to bolster these efforts.

It has been difficult to perform a complete, non-modelled national situation analysis with the Commission's indicators in middle-income countries because of lack of robust, integrated SAO information management systems. So far, efforts have relied on modelled methodologies.¹³ We aimed to undertake a complete situation analysis of the Colombian SAO system preparedness, service delivery, and financial risk protection using the core surgical indicators proposed by the Commission. All six indicators were collected, analysed, and interpreted to contextualise and assess timely, quality, and affordable access to emergency and essential SAO health-care services in Colombia. We augment this analysis by expanding consideration of the essential health-care providers to include nursing, given the essential role of nursing care in ensuring optimal surgical outcomes.^{14,15}

We explore the correlation between the core surgical indicators and socioeconomic status. Finally, we sought to refine the understanding of timely access to a facility capable of providing emergency and essential surgical services.

See Online for appendix 2

Methods

Data sources

Between May 1, 2018, and May 31, 2019, through bidirectional participatory action, Colombian and US members of the Latin American Indicators Research Collaboratory from Fundación Santa Fe de Bogotá (Bogotá, Colombia), Universidad de los Andes (Bogotá, Colombia), and Rutgers University (New Brunswick, NJ, USA), collected, analysed, and interpreted data related to the Commission indicators in Colombia.¹⁶ The primary data sources used for indicator collection were the Colombian national health-care information system Sistema Integral de Información de la Protección Social (SISPRO) and the most recent national health survey, Encuesta Nacional de Salud 2007 (NHS-2007; appendix 2 p 2), which collected data on individual direct and indirect health-care expenditures.¹⁷ SISPRO aggregates administrative, claims, and health services data and includes Los Registros Individuales de Prestación de Servicios de Salud (RIPS; appendix 2 p 2), which is a registry of Colombia's health-care services used for regulation of the health system and includes billing data, and Registro Especial de Prestadores de Servicios de Salud (REPS; appendix 2 p 2), which is a registry of independently billing providers of health-care services in Colombia.

Socioeconomic status by insurance regime

The Colombian health insurance system has three tiers (appendix 2 p 1). The subsidised insurance regime provides health-care coverage for people who earn less than one minimum wage (US\$253 per month) per person at a government-subsidised rate. The contributory regime provides health-care coverage with a scaled mandatory contribution that is proportional to income for individuals earning more than one minimum wage. The exception regime is provided to civil servants and their families. Eligibility for subsidised regime enrolment is determined by the System for Selecting Beneficiaries of Social Spending,¹⁸ which relies on proxy means testing for income and poverty. Thus, we used subsidised regime enrolment as a surrogate marker of lower socioeconomic status. SISPRO was queried by municipality for the number of individuals enrolled in the subsidised, contributory, and exception insurance regimes as of Dec 31, 2016. The proportion of the population enrolled in the subsidised regime (the number of people enrolled in the subsidised regime divided by the number of people enrolled in all regimes) was calculated for each municipality and mapped by municipality by use of ArcGIS Online.

Access to a Bellwether hospital

We assessed 2 h geographical access to a facility capable of providing Bellwether procedures—ie, laparotomy, caesarean section, and open-fracture management—through a three-step process. Unique Classification of Health Procedure (Clasificación Única de Procedimientos

en Salud) codes representing Bellwether procedures¹⁹ (appendix 2 pp 3–8) were used to search RIPS for facilities in which all three procedures had been done in the year 2016, the most recent year containing complete and verified health system data. Candidate facilities were then cross checked by facility name and facility code, yielding a finalised list of Bellwether facilities (appendix 2 pp 9–16). The street address for each Bellwether facility was obtained from REPS.

Bellwether facilities were mapped using a method similar to that previously described by Knowlton and colleagues,²⁰ but with an explicit emphasis on a 2 h drive time. Addresses of the Bellwether facilities were geocoded using ArcGIS Online and a commercial street database (HERE, Q3 2018²¹). Facility location was first confirmed using imagery and data from multiple sources, including Bing Maps and Google Street View. For 142 facilities with locations not clearly verified with other sources, phone calls to the facilities were used to obtain information including the nearest intersection or detailed descriptions of their location. One hospital was omitted from the remainder of the study because of an inability to accurately locate the facility.

When reliable facility locations were established, a 2 h drive time distance was calculated, based on average travel times, and a perimeter was drawn around each facility. Fundamental concerns persist about volunteered geographical information such as OpenStreetMap,^{22,23} with added concerns about ways that socioeconomic and physical landscapes heighten problems of heterogeneous data quality and quantity.^{24,25} Although there is no direct comparison between HERE (Q3 2018)²¹ and OpenStreetMap data for travel impedance in Colombia, Delmelle and colleagues²⁶ found that OpenStreetMap was not comparable in areas with infrequent data contributions, such as rural environments. Given that Colombian representation in OpenStreetMap has been shown to have both fewer contributors and contributions than many other countries,²⁴ we elected to use the Latin American transportation network data from HERE with the proximity tools in ArcGIS Online. Each envelope was calculated based on network routes using Dijkstra's algorithm,²⁷ which applies travel times for streets based on HERE, including real-world transportation considerations of impedance (such as traffic) and restrictions (such as one-way streets) obtained from high-quality vehicle sensor data, government sources, and historical traffic records.²¹

The resulting polygons were dissolved into a single set of boundaries. Collectively, the boundaries covered 17·6 million hectares. To mitigate differences in scale between the source datasets, a second buffer zone was constructed at an additional 5 km outside the 2 h drive time area. This inclusion of areas within this buffer zone accounted for an additional 18·1 million hectares. The analysis incorporated high-resolution raster population estimates.²⁸ These 100 m population density estimates were overlaid with the 2 h drive time boundaries to

For ArcGIS Online see <https://www.arcgis.com/index.html>

calculate the total population within and outside the boundary, and these data were then summarised according to geographical units divided into departments and municipalities. Colombia's 32 departments, which are country subdivisions formed by grouping 1122 municipalities, are granted a certain degree of autonomy. Municipalities represent individual communities, such as towns or cities. A threshold of 20% was chosen to remain consistent with the reciprocal Commission-defined access to a Bellwether facility target of 80% of the population having access by 2030 (table 1).

Physical access to a Bellwether facility within 2 h was determined by presence of a motor vehicle suitable for individual transportation, which was assessed by obtaining national vehicle registration data from the Colombian Department of Transportation from 2000 to 2016.²⁹ Two transportation mode lists were generated. The first list represented personal motor vehicle ownership, which included automobiles, sport utility vehicles, and motorcycles with individual registrations. The second list represented public transportation services using automobiles, buses, sport utility vehicles, and light transport motorised tricycles with public registrations. Presence or absence of these modalities was then determined by municipality. Those individuals residing in a municipality with geographical 2 h access to a Bellwether facility, but without access to either modality, were considered not to have 2 h physical access.

Specialist provider density

To determine the density of the specialist surgical health-care workforce, REPS was queried to generate a list of all registered independent professionals in all medical fields in the year 2016. The resulting dataset was then filtered for specialist surgeons, obstetricians, and anaesthesiologists necessary for the provision of emergency and essential surgical health-care services (appendix 2 p 19).^{19,30} The SAO provider list was cross referenced with membership lists provided by the Colombian Surgical Society and Colombian Society of Anesthesiology and Resuscitation. Representation of surgical specialists and anaesthesiologists in REPS is disparate because of differences in standard billing practices, necessitating parallel approaches to identification. Specialists who bill independently of a facility are catalogued in REPS. Thus, because most surgeons have independent billing privileges, members reported by the Colombian Surgical Society were identified in the REPS query. However, because most anaesthesiologists bill through facilities and therefore are not represented in REPS, we primarily identified anaesthesiologists through the Colombian Society of Anesthesiology and Resuscitation membership list. The Department Administrativo Nacional de Estadística³¹ population projection for 2016 was used to calculate the SAO density. This process was also used to assess SAO density for the year 2018. ArcGIS Online was used to map SAO density by department and municipality. To calculate

the estimated shortfall in Colombia's nursing density, nursing data were obtained from the Organisation for Economic Cooperation and Development.³² Nursing data were correlated with previously published international SAO density data.³³ Mean nursing density in 2017 was compared between countries with an SAO density of 0–19 per 100 000 population versus 20–39 per 100 000 population using Student's *t* test.

Total operative volume

RIPS was queried to determine national total operative volume. The RIPS database contains operative procedure data without procedure location information (ie, operating room vs other). Therefore, a Colombian-based (GEH-A) and two US-based (JSH, GLP) surgeon researchers, all board certified in the clinical practice of emergency and essential surgery, identified Clasificación Única de Procedimientos en Salud codes of operations that were certainly (4063 procedures) or probably (268 procedures) done in an operating theatre. These procedure lists were used to query RIPS to calculate total operative volume for 2016, expressed nationally per 100 000 population and mapped by municipality using similar methods as described for access to a Bellwether facility.

Postoperative mortality

Because of database limitations, in-hospital mortality could not be specified. Given that in-hospital mortality underestimates true 30-day postoperative mortality by approximately 33%, we elected to define postoperative 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.^{1,34} For this calculation, RIPS was queried for all surgical procedures (certain and probable procedures done in an operating room) in 2016 and this output was cross referenced with data from the Department Administrativo Nacional de Estadística mortality database³¹ to determine whether a death was preceded by a surgical procedure. Duplicate entries were then filtered, and the data limited to deaths within 30 days of a procedure. The total number of postoperative deaths that occurred within 30 days of a procedure was then divided by the total operative volume to calculate the all-cause, non-risk-adjusted postoperative mortality. These values were then mapped by department.

Impoverishing expenditure

The most recent Colombian National Health Survey (NHS-2007), which was designed to assess total annual individual health-care expenditures, was administered in 2007 to a total of 164 474 respondents from 41 543 households, aged 0–69 years.¹⁷ Data were abstracted from the NHS-2007 to calculate impoverishing costs incurred from undergoing a surgical procedure in the survey year. Poverty was defined using the 2007 Colombian national poverty line (COL\$295 936 [US\$142])

for urban areas and COL\$243872 [US\$117] for rural areas). Out-of-pocket payments were defined in the survey as the sum of costs related to co-payments for hospitalisation, total hospitalisation bill (for people without insurance), medication-related expenditures, supplies needed, medical tests and x-rays, orthopaedic supplies (eg, splints), outpatient therapies (eg, physical therapy), transportation to and from the hospital (including costs incurred by family members), food, accommodations, photocopies, and lost wages (total cost for the number of days the person or a family member did not work).³⁵ Questions related to surgical cost were asked of those individuals who received surgical care during the previous 12 months. Total out-of-pocket payments were calculated as:

$$\text{Out-of-pocket payments} = \sum_{i=1}^n \text{direct} + \text{indirect costs}$$

where n is the total number of household members.

Household cost impacts were calculated as: impoverishing expenditure = annual household income – out-of-pocket payments $< z_p$, where z_p is the poverty line in 2007. The proportion of the population who were subject to impoverishing costs was calculated by subtracting the baseline number of impoverished individuals from those who fell below the poverty line after out-of-pocket payments were accounted for. Finally, the poverty gap was calculated to assess the effect of out-of-pocket payments from receiving surgical care on people who were already impoverished. This index measures the severity of poverty, or the difference between the current income and the poverty line. The NHS-2007 aggregated data by geographical region (appendix 2 p 20), rural and urban areas, and by household demographics; therefore, we report impoverishing expenditures in a similar manner.

Catastrophic expenditure

To calculate catastrophic expenditures, the NHS 2007 data³⁷ were used to determine the proportion of individuals who underwent a surgical procedure in the survey year. Individuals who incurred out-of-pocket payments that were more than 10% of their annual household income were considered to have experienced catastrophic expenditure.³⁶ As an internal robustness analysis, an out-of-pocket payment threshold of 25% was used to estimate the prevalence of out-of-pocket payments. This analysis was also done considering direct and indirect cost separately. The NHS-2007 aggregated data by geographical region (appendix 2 p 20), rural and urban areas, and by household demographics; therefore, we report catastrophic expenditures in a similar manner.

Statistical analysis

We used Student's t test to assess significance at a p value of less than 0.05 when the mean of two populations were

compared. Pearson's correlation coefficient was used to compare continuous variables when needed.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

By municipality, the proportion of the population enrolled in the subsidised insurance regime ranged from 0 to 98.8% (mean 79% [SD 21], median 87.7% [72.5–93.6], and mode 96.1%). Nationally, 23.3 million (47.7%) of 48.7 million people in the population were enrolled in the subsidised regime as of Dec 31, 2016 (appendix 2 p 17).

Our query of RIPS found 307 geocodable facilities capable of providing all three Bellwether procedures in 2016, of which 178 (58%) facilities were private and 129 (42%) facilities were publicly operated (appendix 2 pp 9–16). We estimated that 41.3 million people (84.9% of the population) had 2 h geographical access to a facility capable of providing a Bellwether procedure. Therefore, at least 7.1 million people (15.1% of the population) did not have timely access to a Bellwether facility, based on geospatial considerations alone. Maps that reveal significant disparities according to comparative geographical location are shown in figure 1. In the most disadvantaged areas—49 of 1122 municipalities—no residents were within 2 h of a Bellwether facility.

The ten most severely disaffected municipalities by the proportion of the population without 2 h geographical access had a disproportionately high enrolment in the subsidised insurance regime, and did not appear to live in proximity to an SAO provider (appendix 2 p 18). Comparison between municipalities with more than 20% of the population outside the 2 h drive envelope from a Bellwether facility and those with less than 20% of the population outside this envelope (544 vs 569 municipalities) showed a significant difference in socioeconomic status as defined by the proportion enrolled in the subsidised insurance regime (mean 84.8% [SD 17.5] across 544 municipalities vs mean 73.4% [22.5] across 569 municipalities; $p < 0.0001$). Finally, of the 118 municipalities that contain the 307 mapped Bellwether facilities, 37 (31.4%) municipalities reported no SAO providers. Notably, 2.4 million people (7.6% of the population) live in these 37 municipalities.

5.3 million motor vehicles were registered in Colombia in 2000–16. Of these vehicles, 221 363 were identified as public transportation vehicles suitable for passenger service. In addition, 4 364 098 vehicles were identified as individually registered vehicles suitable for passenger transportation in 269 municipalities. The remaining 855 municipalities had no public or private vehicles registered. Personal vehicle ownership or the presence of

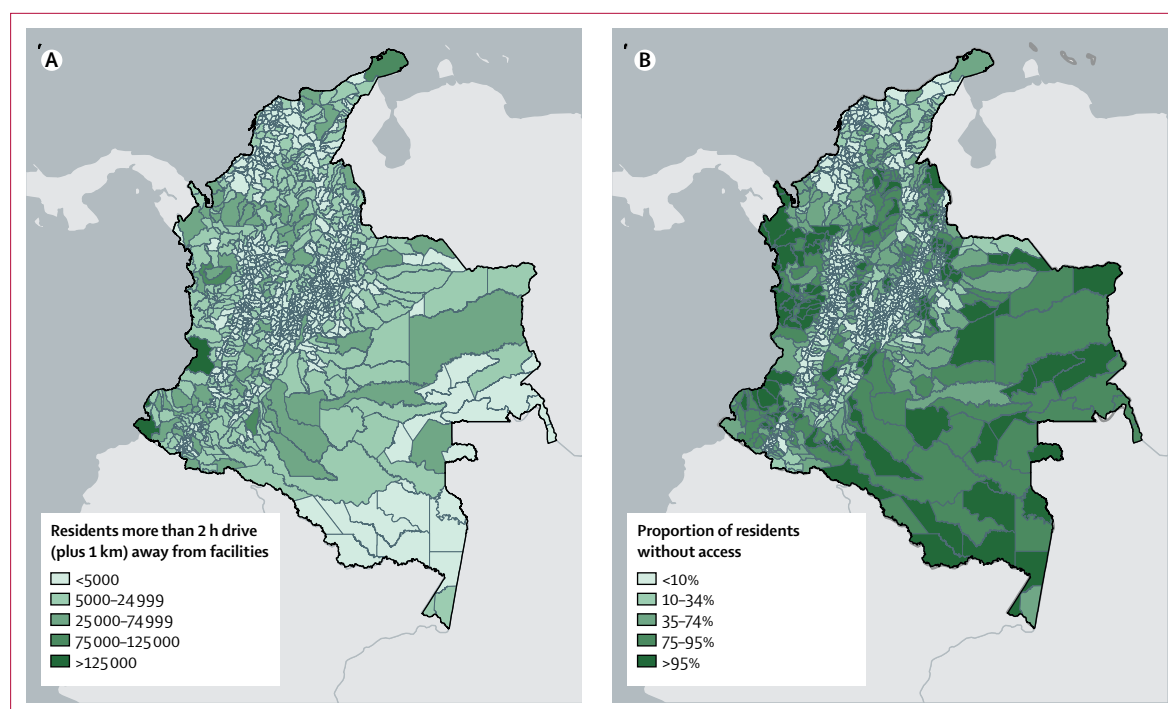


Figure 1: Colombian municipality map showing disparities in 2 h access to a Bellwether facility in absolute numbers (A) and as a proportion of each municipal total (B)

public transportation was inversely proportional to the proportion of people enrolled in the subsidised insurance regime when divided into quartiles ($r=-0.33$, $p<0.0001$). Individuals with 2 h geographical access who lived in municipalities without any registered vehicles were deemed to lack 2 h physical access, which accounted for an additional 7.7 million Colombians (15.7% of the population).

Nationally, SAO provider density in 2016 was approximately 11.9 providers per 100 000 population (table 2). When SAO provider density was mapped, an absence of registered providers was observed in 970 (86.3%) of 1124 municipalities, comprising 16.7 million people (ie, 34.2% of the registered population; figure 2). After excluding outliers (>80 SAO providers per 100 000 population in each of nine [0.8%] municipalities), the observed range of SAO providers across the nation was 0 per 100 000 population to 47.1 per 100 000 population. We found that the most socioeconomically disadvantaged municipalities based on insurance regime enrolment had no SAO providers (mean subsidised insurance regime enrolment of 60.1% [SD 24.7] of residents in municipalities with SAO providers vs 82.0% [SD 18.6] of residents in those without SAO providers; $p=0.0001$). Provider density increased from 2016 to 2018, with an estimated 13.7 providers per 100 000 population in 2018. Finally, nursing complement was estimated at 126 per 100 000 population.

1425 268 procedures were done in 2016. We estimated that between 2690 (certain) and 3090 (certain plus probable)

	Number of providers	Providers per 100 000 population
2016		
Surgery	1906	3.9
Obstetrics	1027	2.1
Anaesthesia	2867	5.9
Total	5800	11.9
2018		
Surgery	2475	5.0
Obstetrics	1337	2.7
Anaesthesia	3002	6.0
Total	6814	13.7

Table 2: Density of surgeons, obstetricians, and anaesthesiologists

procedures per 100 000 population were done. Geospatial analysis revealed 1054 (93.8%) of 1124 municipalities where operative volume was significantly below the Commission's 2030 target of 5000 per 100 000 population (figure 3).

Nationally, we found a postoperative mortality from SAO procedures of 0.73% for the certain plus probable RIPS query (or 0.76% for the certain query) in 2016. For the certain plus probable estimate, we found a median postoperative mortality of 0.74% (IQR 0.48–0.84) across departments. Postoperative mortality was mapped to contextualise the broad range of reported postoperative mortality at the departmental level (appendix 2 p 21). Analysis at the municipal level revealed a negative

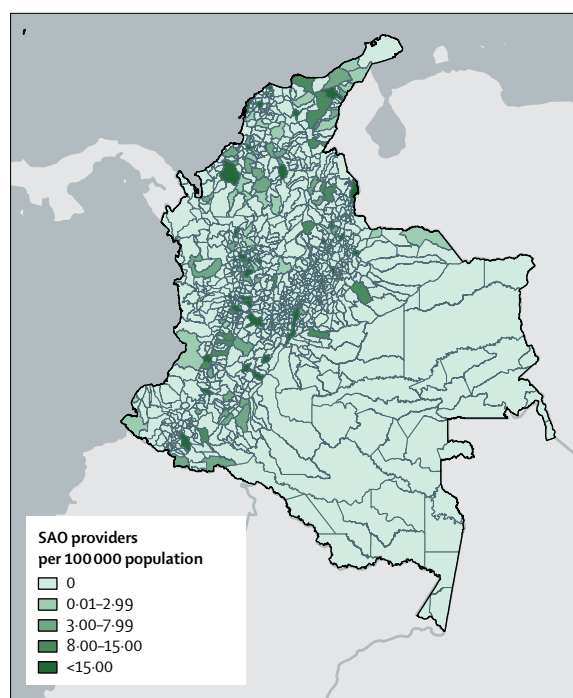


Figure 2: Colombian municipality map demonstrating disparate distribution of SAO providers

SAO=surgical, anaesthetic, and obstetric.

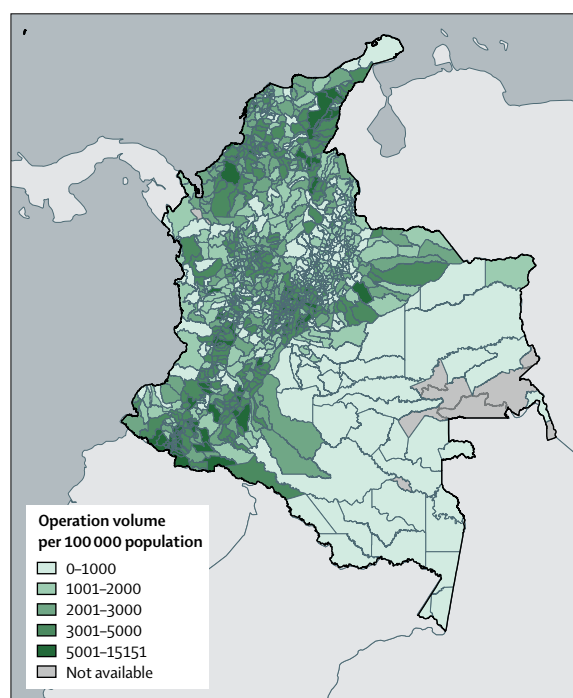


Figure 3: Colombian municipality map demonstrating disparate distribution of operative volumes

correlation between postoperative mortality and higher socioeconomic status ($r=-0.34$, $p<0.0001$). We observed a negative correlation between postoperative mortality and

lack of 2 h geographical access to a Bellwether facility ($r=-0.17$, $p=0.022$). However, we observed a positive correlation between postoperative mortality and SAO provider density ($r=0.31$; $p<0.0001$).

In 2007, the poverty rate for households in which at least one member required SAO health-care services increased by 6.4 percentage points (representing 3.1 million people). By geographical region, the risk of incurring impoverishing expenditure ranged from 3.3 percentage points to 13.2 percentage points (appendix 2 p 22). Furthermore, the poverty gap, representing those individuals pushed further into poverty, increased by 6.2 percentage points when out-of-pocket expenses were incurred for surgical health-care services received (appendix 2 p 23).

In 2007, approximately 9.5 million people (19.4% of the national population) who were admitted to hospital and required surgical health-care services incurred catastrophic expenditures. By geographical region, the chance of catastrophic expenditure ranged from 16.7% (8.1 million people) to 32.4% (15.8 million people; appendix 2 p 24).

Discussion

We have made a systematic determination of the preparedness, service delivery, and cost protection of the SAO health-care system in Colombia and expanded consideration of essential health-care providers to include nursing availability. We used the six core surgical indicators in this complete, non-modelled national-level and local-level surgical system situation analysis. The observed association and correlation of these core surgical indicators with socioeconomic status based on insurance regime are consistent with known social determinants of health care³⁷ and serve to validate the usefulness of these indicators as a foundation for development of a national SAO plan in an upper-middle-income country.

Preparedness of the SAO and nursing system to receive a patient is informed by access to a Bellwether hospital and specialist provider density. Our data suggest that Colombia might be meeting the Commission's 2 h geographical access goal, since around 85% of the population are within 2 h geographical distance from a Bellwether-capable facility (compared with the 2030 target of 80%). However, SAO provider density falls short of the minimum target of 20 providers per 100 000 population, at an estimated density of 13.7 essential SAO health-care providers per 100 000 population in 2018. Service delivery, as measured by total operative volume and postoperative mortality appears to be insufficient to meet the Commission's estimated needs of the registered population. With 2690–3090 procedures done per 100 000 population annually, total operative volume falls short of the Commission's target of 5000 procedures per 100 000 population. Postoperative mortality is estimated to be 0.74%, although without a global risk-adjusted and

regionally contextualised target, it is difficult to benchmark this observation. Finally, it is evident from the impoverishing and catastrophic expenditure risk that a large proportion of the population (up to 32·4% of the population in some areas) is subject to impoverishment and worsening poverty after receiving surgical health-care services.

At least 7·1 million people (15·1% of the population) in Colombia lack 2 h geographical access to a Bellwether facility. Individuals of lower socioeconomic status have a lower likelihood of being within 2 h of a Bellwether facility. This estimate is predicated upon a universally accepted definition of a Bellwether facility, ability to assess access to relevant transportation modalities, and consistent methods for determining reasonable approximations of travel times. So far, these parameters and methodologies have not yet been clearly established. We classified a facility as Bellwether capable if at least one of the representative procedures from each category (laparotomy, caesarean section, or open-fracture care) had been done. This definition assumes that a facility identified in this manner can provide services 24 h a day, 7 days a week. However, many of the identified Bellwether facilities exist where no registered SAO providers are detected: of the 118 municipalities with mapped Bellwether facilities, 37 (31·4%) reported no SAO providers, which might, in part, be explained by a reliance on an itinerant SAO workforce. There is a common practice of SAO providers from more populous cities providing service delivery to underserved areas through *brigadas de salud* (health brigades)^{38,39} and locum-like services (eg, Anesthesiar). Little is known about the size of this itinerant SAO workforce, the volume of essential and emergency operations done, and distribution or capacity across the country. Given the unquantified reliance on itinerant SAO health-care providers, the continuous provision of emergency and essential surgical services by the identified Bellwether facilities is at risk. This problem is exemplified by a 4-month cessation of SAO health-care services delivered by itinerant providers in 2016, because of a US\$2 million deficit in a public Bellwether facility that served a catchment area of approximately 460 000 people. This absence of SAO services resulted in an estimated cancellation of 1900 surgical procedures (M E Diez, Anesthesiar, personal communication). Therefore, it is likely that our current estimate that 84·9% of the population is within 2 h geographical access to continuously functioning Bellwether facilities is an overestimate.

Notwithstanding the impact of SAO provider density on estimation of access to Bellwether procedures, methods of assessing 2 h access are subject to additional limitations. The presented 2 h geographical drive time area was developed using geospatial software with robust transportation network and traffic data. This approach assumes that, when needed, individuals have equal and ready access to emergency medical transportation services or a suitable vehicle. We estimate that an additional 15·7% of

the population (7·7 million people) who are within the geographically defined 2 h drive time area lack access to personal or public transportation means (physical access). Limiting this analysis was the inability to determine emergency medical transportation service availability in all municipalities. This analysis was also limited by the assumption that presence of a registered motor vehicle is directly correlated with access when needed. The observed absence of vehicle registration is consistent with the substantially lower per capita ownership in Colombia (10%) compared with that in the rest of Latin America (18%) and the USA (66%).⁴⁰ In addition, technology and information limitations prevented assessment of public mass transportation system travel time or walking time. Although it is not desirable to rely on foot travel to reach a Bellwether facility, severe traffic congestion (as experienced in the more densely populated areas of Colombia) or lack of access to an automobile might result in no other alternative. Finally, we do not address other physical barriers such as the *zonas rojas* (red zones), where unsafe travel conditions related to civil unrest or crime further limit access. Despite these limitations, we estimate that approximately 30·8%, which is the sum of those individuals without geographical and physical access (15·1% and 15·7%, respectively), do not have timely access to a Bellwether facility.

Colombia's national SAO provider density of 13·7 per 100 000 population in 2018, which has improved from 11·9 per 100 000 population in 2016, falls short of the Commission's target of 20 providers per 100 000 population. On the basis of an optimal workload to achieve total operative volume and Human Development Index data, it has been proposed that between four and five of the target SAO providers per 100 000 population should be anaesthesiologists.^{30,41} We estimate that there were approximately 5·9 anaesthesiologists per 100 000 population in 2016 and 6·0 anaesthesiologists per 100 000 population in 2018, suggesting a severe shortage of surgeons and obstetricians. Geospatial analysis revealed significant regional maldistribution of the current SAO health-care workforce, with 86·3% of municipalities lacking SAO providers, which accounts for 34·2% of the population (approximately 16·7 million people). Notably, municipalities with the most socioeconomically disadvantaged populations appear to have no identifiable SAO providers. Individuals who are socioeconomically disadvantaged are 1·4 times less likely to have access to an SAO provider in the municipality in which they reside, as demonstrated in this study. By cross referencing provider registration in REPS and provider participation in the respective societies, we hope to have minimised potential information and measurement bias. Because of database limitations, we were unable to confirm specialist completion of postgraduate-specific education and training.

In addition to considering the Commission's definition of SAO, we propose that SAO health-care provider density

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should be considered relative to the available nursing workforce. Inadequate nursing ratio and system integration has been associated with increased 30-day mortality for all inpatient admissions.^{14,15} In Colombia, the nursing complement, estimated at 126 per 100 000 population, is 7·1 times lower than that of Turkey, Ireland, Japan, Canada, China, Denmark, and New Zealand, which have an SAO provider density of 20–40 per 100 000 population.⁴² Despite this markedly low density of nurses, with 0·69 times the minimum SAO provider density and 0·14 times the predicted needed nursing ratio, the observed total operative volume is 0·62 times the target volume. These data suggest that Colombian providers appear to be working at or beyond capacity while maintaining a median postoperative of 0·74%, with a fraction of the necessary nurses.

Colombian 30-day all-cause, postoperative mortality was calculated as 0·73% to 0·76%. Recent efforts have been made to estimate global postoperative mortality as a reference benchmark.^{43,44} Nepogodiev and colleagues estimated the non-risk-adjusted global postoperative mortality to be about 1·34%.⁴⁴ Perioperative factors such as distribution and extent of indigenous social and environmental epidemiology, timely access to a Bellwether facility, and primary, secondary, and tertiary prevention measures directly affect postoperative mortality. Thus, risk adjustment is essential to contextualise any nation's observed postoperative mortality. The observed increase in postoperative mortality in some municipalities correlating with municipalities with a higher level of 2 h Bellwether facility access, proximity to higher densities of SAO providers, and higher socioeconomic status is curious. It is possible that as resources improve, SAO providers are delivering care to a challenging volume of patients, patients with a greater number of risk factors, or doing higher-risk operations, resulting in higher postoperative mortality. Alternatively, measurement bias—ie, incomplete mortality reporting—might contribute to this counterintuitive observation.

We estimate that nearly 6·4% of the population sustained impoverishing expenditures as a result of requiring SAO health-care services. When these data were analysed for people already living below the national poverty line, the poverty gap increased by 6·2 percentage points as a result of out-of-pocket payments. Furthermore, 19·4% of the population sustained catastrophic out-of-pocket payments. It is important to note that most individuals incurring direct costs also incurred indirect costs in 2007. Approximately 90% of individuals who incurred indirect costs were income poor. By comparison, in 2017, the first complete dataset available through the World Bank Group on impoverishing and catastrophic expenditures, 18·8% of individuals seeking surgical care sustained impoverishing costs and 20·7% of individuals sustained catastrophic costs in upper-middle income countries. By contrast, in high-income countries, 0·44% of individuals faced impoverishing costs and 1·66% faced catastrophic costs (see World Bank indicators).

These findings are reflected in previously reported attitudes and beliefs towards health-care expenditures in Colombia. A substantial proportion of the population queried cited lack of money (42–58% of survey respondents when stratified by income quintiles) as the primary reason for not using health-care services.⁴⁵ This concern was consistent whether respondents lived in urban (45% of respondents) or rural areas (55% of respondents).⁴⁵ The implications of these findings should be interpreted in light of changes to the Colombian national health insurance system in 2011 and decrease in the population poverty index. This health-care reform aimed to equalise the health-care benefit packages between the subsidised and contributory regimes, and to increase the proportion of direct costs that would be covered.¹¹ Although the impact of direct costs on impoverishment and catastrophic expenditures might be reduced, indirect costs alone result in a considerable increase in the poverty rate and poverty gap. Furthermore, out-of-pocket payments for medical care, as a proportion of insured consumers' health-care expenditures, remain high (61·7% in 2014 vs 64% in 2011; see World Bank indicators). Therefore, although considerable progress has been made, the population's most vulnerable citizens remain at highest risk for impoverishing health-care expenses.

Recognition of the indivisible nature of medical and surgical care⁴⁶ in achieving optimal outcomes for the population combined with this situation analysis presents Colombia with a unique opportunity to fulfil its constitutional mandate for universal health care. A situation analysis begins to inform the what, how, and why of ensuring universal access to surgical health-care services when needed. Our situation analysis process has afforded stakeholders the opportunity to establish a productive, bidirectional collaboration with the Colombian Ministry of Health. To achieve timely and relevant change, this collaboration must transcend academic discourse through development, implementation, and evaluation of evidence-based clinical and policy interventions that positively affect population health outcomes. The Ministry of Health's commitment to incorporate the indicators proposed by the Commission in a national health metrics dashboard represents a step forward to facilitate greater transparency informing Colombia's process for the development of a national SAO plan.

Colombia has completed an indicator-based situation analysis of the SAO health-care system. The observed association of these indicators and their correlation with socioeconomic status are consistent with well recognised factors and outcomes that affect a nation's social, health, and health-care equity. The internal consistency observed in Colombia's situation analysis validates the use of the indicators proposed by the Commission as an objective foundation⁴⁷ for the development, implementation, and evaluation of a national SAO plan. Four key messages emerge from this situation analysis. First, an increased

incidence of poverty is associated with a lower likelihood of being within 2 h of a Bellwether facility or of living in a municipality without an SAO provider. Second, out-of-pocket payments for indirect costs are a real barrier to accessing surgical health care. Third, Colombian SAO providers appear to be working at or beyond capacity while maintaining relatively low postoperative mortality of 0.74%. Last, Colombia is poised to develop a comprehensive health-care plan that incorporates SAO system strengthening in the Territorial Comprehensive Action Model and Immediate Action Program for Hospitals via the next iteration of the Public Health Decennial Plan, which is due in 2022.

Contributors

JSH and GLP substantially contributed to the conception and design of the study, and to acquisition, analysis, and interpretation of the data, and drafted the manuscript. GEH-A substantially contributed to the conception and design of the study and to acquisition, analysis, and interpretation of the data, and participated in drafting of the manuscript. MP-R, DT, SAV, MES, CH, SUR, and AKM substantially contributed to the acquisition, analysis, and interpretation of the data, and drafting and revision of the manuscript. LCGB, MFMS, MAPN, RN, MS, and MVR substantially contributed to the acquisition, analysis, and interpretation of the data, and revision of the manuscript. MP-B, AMR, and ID-G substantially contributed to the analysis and interpretation of the data, and revision of the manuscript. DL substantially contributed to the conception and design of the study, and revision of the manuscript. VG substantially contributed to the conception and design of the study, interpretation of the data, and revision of the manuscript.

Declaration of interests

JSH reports grants from Zoll Medical (during the conduct of the study). MP-B reports that she currently works as an adviser to the Minister of Health and Social Protection of Colombia. ID-G reports that he has been Vice Minister of Health and Social Protection of Colombia since September, 2018, and is currently Minister of Health and Social Protection in Charge. GLP reports grants from Zoll Medical (during the conduct of the study), and academic partnership relationships with Nivaldo Alonzo and John Meara, two Commissioners of the *Lancet* Commission on Global Surgery. All other authors declare no competing interests.

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