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ORIGINAL RESEARCH

Assessment of Surgical and Trauma Capacity in Potosí, Bolivia

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Abstract

BACKGROUND Scaling up surgical and trauma care in low- and middle-income countries could prevent nearly 2 million annual deaths. Various survey instruments exist to measure surgical and trauma capacity, including Personnel, Infrastructure, Procedures, Equipment, and Supplies (PIPES) and International Assessment of Capacity for Trauma (INTACT).

OBJECTIVE We sought to evaluate surgical and trauma capacity in the Bolivian department of Potosí using a combined PIPES and INTACT tool, with additional questions to further inform intervention targets.

METHODS In June and July 2014 a combined PIPES and INTACT survey was administered to 20 government facilities in Potosí with a minimum of 1 operating room: 2 third-level, 10 second-level, and 8 first-level facilities. A surgeon, head physician, director, or obstetrician-gynecologist completed the survey. Additional personnel responded to 4 short-answer questions. Survey items were divided into subsections, and PIPES and INTACT indices calculated. Medians were compared via Wilcoxon rank sum and Kruskal-Wallis tests.

FINDINGS Six of 20 facilities were located in the capital city and designated urban. Urban establishments had higher median PIPES (8.5 vs 6.7, $P = .11$) and INTACT (8.5 vs 6.9, $P = .16$) indices compared with rural. More than half of surgeons and anesthesiologists worked in urban hospitals. Urban facilities had higher median infrastructure and procedure scores compared with rural. Fifty-three individuals completed short-answer questions. Training was most desired in laparoscopic surgery and trauma management; less than half of establishments reported staff with trauma training.

CONCLUSIONS Surgical and trauma capacity in Potosí was most limited in personnel, infrastructure, and procedures at rural facilities, with greater personnel deficiencies than previously reported. Interventions should focus on increasing the number of surgical and anesthesia personnel in rural areas, with a particular focus on the reported desire for trauma management training. Results have been made available to key stakeholders in Potosí to inform targeted quality improvement interventions.

KEY WORDS Bolivia, Latin America, global surgery, essential surgery, trauma, surgical capacity

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INTRODUCTION

An estimated 2 million lives could be saved annually through increased access to basic surgical care and further development of trauma care systems in low- and middle-income countries (LMICs).[1-3] A critical step in the development of comprehensive trauma care systems is for health care facilities to assess baseline surgical and trauma capacity strengths and weaknesses.[4,5] Data from these assessments can inform targeted, locally relevant quality improvement interventions for surgical or trauma care, as well as provide the ability to compare facility capabilities at departmental and national levels. Multiple survey instruments have been used for the assessment of these capacities in LMICs; however, few have been completed in Latin America, with 2 focusing on the Plurinational State of Bolivia (Bolivia).[6-8]

Bolivia is a lower-middle income country in central South America with a population of 10.8 million and a median age of 23.7 years.[9,10] Among Latin American countries, Bolivia ranks poorly on several health and development indicators, such as mortality (6.52 deaths per 1000) and life expectancy (68.86 years).[10] Bolivia also has the highest income inequality in Latin America, with 45% of the population living below the poverty line.[10] Specifically regarding injuries, Bolivia has one of the highest road traffic injury death rates in Latin America (23.2 deaths per 100,000), behind only Brazil and Belize according to the World Health Organization (WHO) 2015 Road Safety Report.[11]

Potosí is 1 of 9 administrative departments within Bolivia, covering 118,218 km^2 in the southwestern corner of the country.[12] In 2012, the population was 823,517, with just over 20% living in the capital city, also named Potosí. This department has the lowest percentage of urban inhabitants of all Bolivian departments and is also distinct for its high level of poverty, prevalent mining community, unsafe mountain roads, and high altitudes, with an average elevation of 3,977 meters above sea level.[12,13] Such factors limit not only access to health care but challenge the development of surgical and trauma care systems, which are vital in a country plagued by high rates of road traffic injuries and a department where treacherous roads and labor-intensive jobs leave inhabitants particularly at risk for injury.

A prior countrywide assessment of surgical capacity in Bolivia included 2 facilities in Potosí; however, an in-depth evaluation of the surgical and trauma care capacity in the more rural, less developed regions of the country has yet to be performed.[6] We sought to determine baseline surgical and trauma care capacities at government health care facilities in Potosí through the application of the Personnel, Infrastructure, Procedures, Equipment, and Supplies (PIPES)[14] and the International Assessment of Capacity for Trauma (INTACT)[15] survey instruments, with this study being the first known prospective application of the INTACT tool. Collected capacity data will provide a more comprehensive picture of the spectrum of surgical and trauma care available across Bolivia and can be used to inform targeted, locally relevant improvement plans for the department of Potosí, with a particular focus on self-determined areas of need.

MATERIALS AND METHODS

Survey Instrument. Among the many survey instruments developed for the evaluation of surgical and trauma care capacity in LMICs, the first to focus on surgical care was the WHO's Tool for Situational Analysis to Assess Emergency and Essential Surgical Care (TSAAEESC).[16] Surgeons OverSeas (SOS) modified TSAAEESC to create PIPES, which introduced a binary system of measurement by limiting respondents to the choice of whether resources or procedures were *available/performed* or *not available/not performed.*[14] PIPES contains 105 data points, organized into personnel, infrastructure, procedures, equipment, and supply sections. Evaluations of surgical care capacity have been conducted in at least 12 countries using PIPES.[8] PIPES was subsequently modified to focus on trauma-specific surgical care via INTACT.[15] The 40-question INTACT survey includes only those PIPES items specific to trauma, with the addition of cervical collars, which is not present in PIPES.

In our evaluation of surgical and trauma care capacity at facilities in Potosí, we used a combined PIPES and INTACT survey instrument of 106 questions. For a separate inter-rater reliability assessment, the equipment and supplies sections were modified to include all equipment and supplies items originally present in TSAAEESC, as well as the additional response option of *sometimes available*. For the purpose of the present study, only results from PIPES and INTACT items are included. To maintain the original PIPES and INTACT binary response system, the response of

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sometimes available in the equipment and supplies sections was scored as *not always available.*

Four additional short-answer questions not present in PIPES or INTACT were included, which assessed commonly performed procedures, desired training, and referral access:

1. Which surgeries are performed most frequently at this facility?
2. In which procedures do you desire training?
3. Has anyone at this facility received training in trauma care?
4. What is the distance to the nearest referral hospital?

No prompts or answer choices were provided for short-answer questions, and respondents were not given a limit on the number of responses they could provide to question 1 or 2. PIPES was previously translated into Spanish for the assessment of facilities in Santa Cruz, Bolivia.[7] Newly added survey items and short-answer questions were translated and verified by one of the authors (J.L.G.B.).

Site Selection and Data Collection. Bolivia's health care system is divided into public, social security, private, and traditional medicine sectors.[17,18] The public sector provides care to around 40% of the population and is under the governance of the Ministry of Health and Sports (*Ministerio de Salud y Deportes* [MSD]), the departmental level of which is known as Departmental Health Services (*Servicio Departamental de Salud* [SEDES]).[18] Three specific populations receive insurance through the public sector: minors younger than age 5 and women who are pregnant, through Universal Maternal and Child Insurance, and adults older than age 60, through Health Insurance for Older Adults.[18,19] The social security sector serves nearly 30% of the population, namely organized, salaried workers and their dependents, and is financed by employers, employees, and the government. The private sector consists of for-profit and not-for-profit facilities, as well as nongovernmental organization (NGO) and church-affiliated facilities.[18]

Medical facilities in Bolivia are classified as either first-, second-, or third-level.[20] First-level facilities offer basic care and are known as health posts *(puestos de salud)* or health centers *(centros de salud).* Second-level facilities, also known as basic hospitals, are more specialized and have 4 specialties: internal medicine, surgery, pediatrics, and obstetrics and gynecology; they may or may not have anesthesiology. It is these second-level centers in Bolivia that fall under the category of district hospital, a designation used by the WHO.[21] Lastly, third-level facilities are large, multispecialty hospitals located in departmental capital cities across Bolivia.[17]

The present study was conducted in coordination with SEDES Potosí. Selected sites were government health care facilities, either public or social security, with at least 1 operating room (OR). Private facilities were excluded, as there were not any second- or third-level private, NGO, or church-affiliated hospitals in the department.[16,20] SEDES staff identified 22 government facilities in the department of Potosí with at least 1 OR, not all of which were functional. One first-level facility was excluded for geographic reasons; an additional second-level facility was identified after data collection was completed and was thus excluded from the study. A total of 20 facilities were included in this assessment.

Data collection occurred during a 6-week period in June and July 2014. SEDES informed all hospitals of the upcoming visits via fax, and site visits were conducted individually or jointly by 2 of the authors (K.J.B., J.L.G.B.). Visits lasted between 1 and 4 hours depending on staff availability. At each facility a surgeon, head physician, director, or obstetrician-gynecologist (OB/GYN) completed the combined PIPES and INTACT survey. Multiple additional personnel at each facility were asked to respond to the 4 short-answer questions at the end of the survey. Personnel were chosen to respond to the additional questions based on their availability at the time of administration; respondents included general surgeons, head physicians, directors, OB/GYNs, anesthesiologists, a pediatrician, and nurses.

Data Analysis. Both PIPES and INTACT are divided into personnel, infrastructure, procedures, equipment, and supplies sections, with scores calculated for each. The detailed scoring process has been previously described in Groen et al[14] and Wong et al[15] for PIPES and INTACT, respectively. Overall PIPES and INTACT indices are calculated by adding the scores from the 5 sections, dividing by the total number of items, and then multiplying by 10. After removal of a mistranslated item in the equipment section, PIPES contains 104 questions. INTACT contains 40 total items. Of note, PIPES grants points for each essential personnel member and functional operating room, leaving the personnel and infrastructure sections with no maximum total score. The PIPES index, therefore, may be higher than 10, whereas the maximum INTACT index is 10. Higher PIPES scores correspond to greater overall surgical capacity, and higher INTACT scores correspond to greater trauma-specific surgical capacity.

Median PIPES and INTACT section scores and indices were compared between urban and rural facilities via the Wilcoxon Rank Sum test and by facility level via the Kruskal Wallis test. A P value $\leq .05$ was considered significant.

This investigation was done with the approval and oversight of SEDES Potosí, and all collected data were provided back to SEDES after analysis. Because human participants were not involved in this investigation and no patient data were collected, the Northwestern University Institutional Review Board did not require review.

RESULTS

Twenty public or social security health facilities were assessed across 10 of the 16 provinces in the department of Potosí (Fig. 1, Table 1). The 6 facilities in the departmental capital, Potosí, were located in the Urban Potosí health network and thus designated urban; the remaining 14 facilities were designated rural. Of the 20 included facilities, 8 were first-level, 10 were second-level, and 2 were third-level facilities. The 2 third-level facilities, Daniel Bracamonte and Caja Nacional de Salud, were both located in the capital of Potosí. There was a trend toward higher median PIPES (8.5 vs 6.7, $P = .11$) and INTACT (8.5 vs 6.9, $P = .10$) indices at urban versus rural facilities (Table 2). Additionally, median PIPES and INTACT indices sequentially increased from first- to second- to third-level facilities.

Personnel. There were a total of 24 general surgeons (3.0 per 100,000 population) and 19 anesthesiologists (2.4 per 100,000 population) in the department of Potosí (Table 3). More than half of Potosí's personnel are located in the 5 urban second- and third-level hospitals, with the remaining 11 general surgeons (1.8 per 100,000 population) and 5 anesthesiologists (0.8 per 100,000 population) covering the majority rural population. The mean number of general surgeons and anesthesiologists per facility was 1.1 and 0.8 at second-level hospitals, and 5.5 and 5.5 at third-level hospitals. Two of the eight first-level hospitals had a general surgeon, and none had an anesthesiologist. No facility reported general physicians who operate. Fourteen facilities indicated they had at least 1 surgical subspecialist (OB/GYNs, orthopedic surgeons, etc.).

Infrastructure. Urban facilities had significantly higher median PIPES (12.0 vs 8.0, $P = .04$) and INTACT (5 vs 3.5, $P = .03$) infrastructure scores. No rural facility had an intensive care unit or functioning computed tomography; the two third-level hospitals were the only 2 facilities outfitted with a functioning computed tomography machine. Two facilities indicated they had a blood bank. Additional results are provided in Table 4.

There were a total of 29 functional ORs (3.7 per 100,000 population) in the department of Potosí, 15 at rural facilities (2.4 per 100,000 population) and 14 at urban facilities (8.4 per 100,000 population). The majority of ORs in the department were present in the second- and third-level hospitals. Four first-level facilities indicated their OR was nonfunctional. Of the 4 first-level facilities with functional ORs, 2 facilities had a surgeon on staff and none had an anesthesiologist.

Procedures. The most commonly performed procedures included suturing, wound debridement, burn management, splinting, and local anesthesia administration. Procedures least commonly performed fell within the pediatric surgery category, specifically repairs of pediatric abdominal wall defects, imperforate anus, clubfoot, and cleft lip. Table 5 presents all 40 procedure items, divided into 10 surgery categories as previously described by Henry et al.[22]

There was a trend toward higher median PIPES (32.5 vs 17.5, $P = .19$) and INTACT (13.0 vs 9.0, $P = .32$) procedure scores at urban versus rural facilities. Six of the 7 rural, second-level facilities indicated they were able to perform an appendectomy, strangulated hernia repair, and cholecystectomy; all 7 were able to perform cesarean section (C-section) and elective hernia repair. With regard to trauma management in rural Potosí, 6 of the 7 second-level facilities and 3 of 7 first-level facilities indicated they were able to provide resuscitation. Five of the 7 rural, second-level centers stated they were able to perform tracheostomy, cricothyroidotomy, and chest tube placement.

Delivery of local or regional anesthesia was offered by 85% of surveyed facilities. Spinal anesthesia was offered at 65% of facilities, ketamine at 70%, and general anesthesia at 65%. Nearly all of the second- and third-level facilities offered all 4 types of anesthesia. Five of the 8 first-level centers offered local anesthesia, 2 ketamine, and 1 spinal and general anesthesia.

Equipment and Supplies. Urban and rural facilities had similar median PIPES (19.5 vs 18.0, $P = .59$) and INTACT (10.0 vs 9.5, $P = .25$) equipment

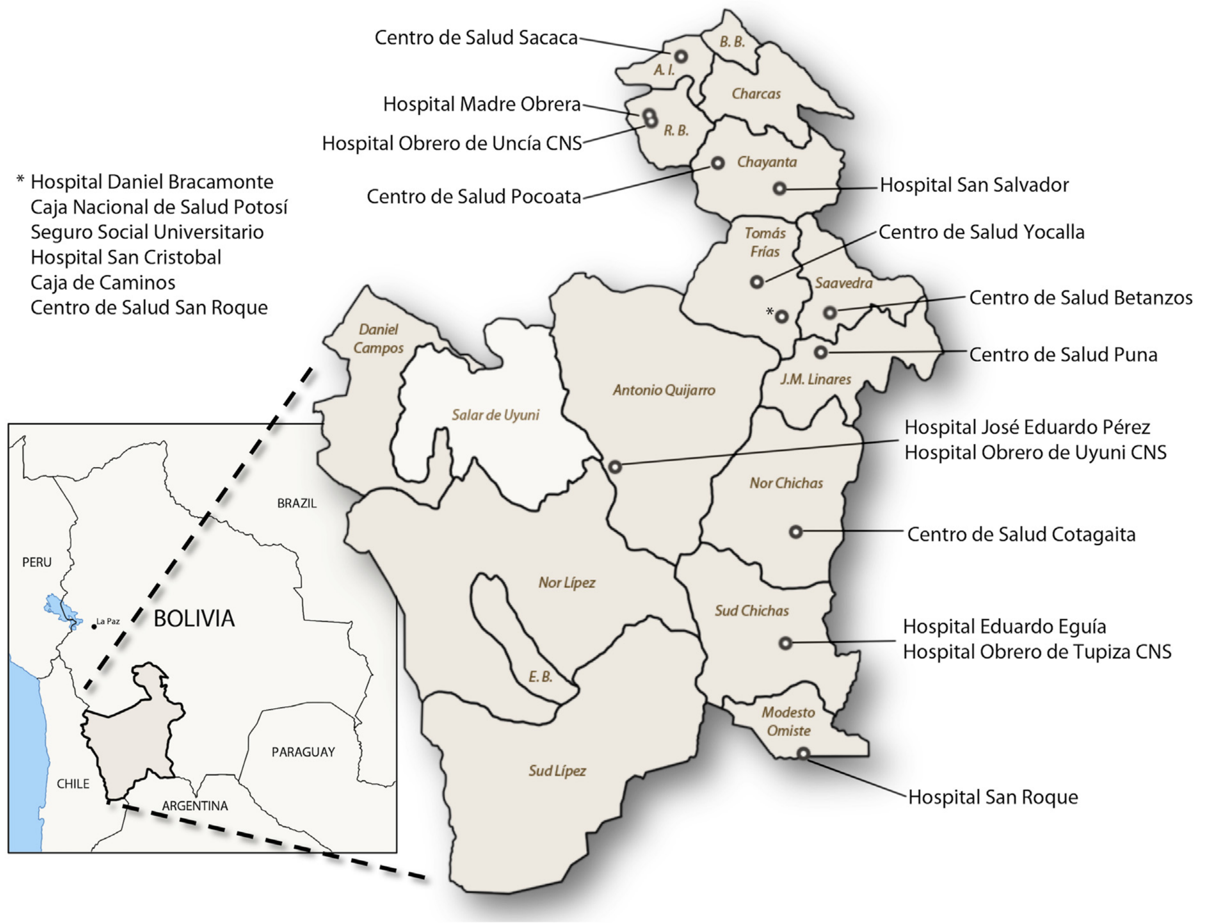

Figure 1. Map of public and social security hospitals with at 1 one operating room in the department of Potosí, Bolivia. The map depicts the location of included hospitals within the 16 political provinces of the department of Potosí, with additional information provided in Table 1. Abbreviated provinces are as follows: A.I., Alonzo de Ibánez; B.B., Bernardino Bilbao; E.B., Enrique Baldivieso; R.B., Rafael Bustillo. Only those hospitals included in data analysis are indicated on the map. Some cities had more than 1 hospital; the 6 hospitals located in the capital city of Potosí were designated urban. The lighter shaded area is the Salar de Uyuni (Salt Flats), which is sparsely inhabited.

scores and equivalent PIPES (22.0 vs 22.0, $P = .70$) and INTACT (4.0 vs 4.0, $P = .92$) supplies scores. Basic equipment and supplies, such as stethoscopes, thermometers, vaginal speculums, syringes, needles, and gauze, were available at all 20 facilities. The equipment and supply items least commonly available included endoscopes, personal eye protection, chest tubes, tracheostomy tubes, and laparoscopic surgery supplies. Of the 5 rural, second-level centers that performed chest tube placements, 2 indicated that chest tube insertion equipment was not always available. Two of the 8 facilities responding as able to perform laparoscopic surgery did not have reliable access to laparoscopic surgery equipment.

Short-Answer Responses. A total of 53 of 56 queried individuals completed the additional short-answer questions, representing roughly half of the general surgeons and anesthesiologists working in Potosí's government health care sector. Eight respondents from first-level facilities did not provide an answer to question 1, indicating their OR was not used because of a lack of personnel. Of those who responded to question 1, the most often cited surgeries both overall and at second- and third-level facilities were cholecystectomy, C-section, appendectomy, and hernia repair. Personnel from first-level facilities cited C-section as the most commonly performed surgery.

Table 1. Public and Social Security Hospitals with At Least 1 Operating Room in the Department of Potosí, Bolivia[*]

Province	Population[†]	Hospital Name	Health Network	Facility Type	Level of Facility	City of Nearest Referral Hospital	Distance to Referral Hospital	Estimated Time to Referral Hospital
Tomás Frías	210,812	Hospital Daniel Bracamonte	Urban Potosí	Public	Third	La Paz	540 km	8 hr
		Caja Nacional de Salud – Potosí	Urban Potosí	Social Security	Third	Sucre	150 km	2.5 hr
		Hospital San Cristobal	Urban Potosí	Public	Second	Potosí	<5 km	<20 min
		Seguro Social Universitario	Urban Potosí	Social Security	Second	Potosí	<5 km	<20 min
		Caja de Caminos	Urban Potosí	Social Security	Second	Potosí	<5 km	<20 min
		Centro de Salud San Roque	Urban Potosí	Public	First	Potosí	<5 km	<20 min
		Centro de Salud Yocalla	Rural Potosí	Public	First	Potosí	45 km	≤1 hr
Alonzo de Ibáñez (A.I.)	32,714	Centro de Salud Sacaca	Sacaca	Public	First	Oruro	100 km	3.5 hr
Bernardino Bilbao (B.B.)	11,330	—	Sacaca	—	—	—	—	—
Charcas	46,510	—	Sacaca	—	—	—	—	—
Rafael Bustillo (R.B.)	75,506	Hospital Madre Obrera—Llallagua	Uncía	Public	Second	Oruro	90 km	1.5 hr
		Hospital Obrero de Uncía CNS	Uncía	Social Security	Second	Oruro	100 km	2 hr
		Centro de Salud Chayanta[‡]	*Uncía*	*Public*	*First*	—	—	—
Chayanta	110,886	Centro de Salud Pocoata	Ocurí	Public	First	Llallagua	75 km	2.5 hr
		Hospital San Salvador	Ocurí	Public	First	Sucre	100 km	4 hr
Cornelio Saavedra	65,549	Centro de Salud Betanzos	Betanzos	Public	First	Potosí	45 km	≤1 hour
José María (J.M.) Linares	50,699	Centro de Salud Puna	Puna	Public	First	Potosí	65 km	≤1 hour
Nor Chichas	32,997	Centro de Salud Cotagaita	Cotagaita	Public	First	Potosí	170 km	3 hr
Sud Chichas	44,287	Hospital Eduardo Equía	Tupiza	Public	Second	Potosí	250 km	4 hr
		Hospital Obrero de Tupiza CNS	Tupiza	Social Security	Second	Potosí	250 km	4 hr
Sud Lípez	5780	—	Tupiza	—	—	—	—	—
Antonio Quijarro	39,184	Hospital José Eduardo Pérez	Uyuni	Public	Second	Potosí	200 km	3.5 hr
		Hospital Obrero de Uyuni CNS	Uyuni	Social Security	Second	Potosí	200 km	3.5 hr

(*continued on next page*)

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Table 1. continued

Province	Population[†]	Hospital Name	Health Network	Facility Type	Level of Facility	City of Nearest Referral Hospital	Distance to Referral Hospital	Estimated Time to Referral Hospital
Daniel Campos	5566	—	Uyuni	—	—	—	—	—
Enrique Baldivieso (E.B.)	2045	—	Uyuni	—	—	—	—	—
Nor Lípez	13,089	—	Uyuni	—	—	—	—	—
Modesto Omiste	41,452	Hospital San Roque	Villazón	Public	Second	Tarija	200 km	4 hr
		Hospital Obrero de Villazón CNS[‡]	*Villazón*	*Social Security*	*Second*	—	—	—

* The table lists all public and social security hospitals with at least 1 operating room in the department of Potosí. Hospitals are organized according to the political province in which each is located, as depicted in Figure 1. Each hospital belongs to 1 of 11 health networks within the department, which may cover more than 1 province.
† Population data gathered from the Bolivian National Institute of Statistics (Instituto Nacional de Estadística. Potosí: Proyecciones de Población, Por Sexo, Según Municipio, 2000-2010. La Paz, Bolivia: Instituto Nacional de Estadística. Available at: http://www.ine.gob.bo/index.php.)
‡ Excluded facilities not depicted in Figure 1 are presented in *italics*; Centro de Salud Chayanta has an OR that is non-functional due to lack of staff, Hospital Obrero de Villazón CNS was identified after study period.

Respondents from second- and third-level hospitals were most interested in laparoscopic surgery training; a majority of general surgeon respondents indicated they desired training in laparoscopic surgery. Personnel from second-level hospitals also desired training in trauma management and subspecialist procedures. Only 7 of the 20 surveyed facilities had staff with specific training in trauma care. Tables 6 and 7 present responses to question 2, organized by facility type and respondent specialty type, respectively.

Distance and estimated time to referral hospitals are presented in Table 1. Mean distance to a referral hospital from first- and second-level facilities was significantly greater in rural versus urban settings (135.0 km vs 2.1 km, $P < .0001$).

Table 2. Median PIPES and INTACT Section and Overall Index Scores by Location and Facility Level*

Tool	Section	Location			Level of Facility			
		Rural (n = 14)	Urban (n = 6)	*P*	First (n = 8)	Second (n = 10)	Third (n = 2)	*P*
PIPES[†]	PIPES Index	6.7	8.5	.11	4.2	8.3	10.5	<.001
	Personnel	1.0	2.5	.23	0.0	2.0	11.0	<.001
	Infrastructure	8.0	12.0	.04	7.5	9.0	16.5	.002
	Procedures	17.5	32.5	.19	7.0	32.0	37.5	<.001
	Equipment[‡]	18.0	19.5	.59	12.0	20.0	20.5	.005
	Supplies	22.0	22.0	.70	21.0	22.0	23.5	.02
INTACT[§]	INTACT Index	6.9	8.5	.10	3.8	8.3	9.5	<.001
	Personnel	1.0	2.0	.31	0.0	2.0	2.0	<.001
	Infrastructure	3.5	5.0	.03	2.5	4.0	6.5	.004
	Procedures	9.0	13.0	.32	5.5	14.0	14.5	.002
	Equipment	9.5	10.0	.25	6.0	10.0	11.0	.002
	Supplies	4.0	4.0	.92	3.0	4.0	4.0	.08

INTACT, International Assessment of Capacity for Trauma; PIPES, Personnel, Infrastructure, Procedures, Equipment, and Supplies.
* Index and section scores were compared between rural and urban facilities via the Wilcoxon Rank Sum test and by facility level via the Kruskal Wallis test.
† PIPES contains a total of 105 items divided into Personnel (4 items), Infrastructure (14 items), Procedures (40 items), Equipment (22 items), and Supplies (25 items) sections. Index score is calculated by taking a hospital's total score divided by 105, multiplied by 10; PIPES Index scores may be greater than 10.
‡ One PIPES equipment item was mistranslated and removed from analysis, leaving the equipment section with 21 items and the tool with a total of 104 items.
§ INTACT contains a total of 40 items divided into Personnel (2 items), Infrastructure (7 items), Procedures (16 items), Equipment (10 items), and Supplies (5 items). Index score is calculated by taking a hospital's total score divided by 40, multiplied by 10; INTACT Index scores have a maximum value of 10 because only 1 point is scored for any number of personnel.

Table 3. Number of General Surgeons and Anesthesiologists Organized by Location and Level of Facility*

Personnel Item	All Facilities No. Personnel (per 100,000 population)†	Rural No. Personnel (per 100,000 population)	Urban No. Personnel (per 100,000 population)	First Level No. Personnel (mean per facility)‡	Second Level No. Personnel (mean per facility)	Third Level No. Personnel (mean per facility)
General surgeons	24 (3.0)	11 (1.8)	13 (7.8)	2 (0.3)	11 (1.1)	11 (5.5)
Anesthesiologists	19 (2.4)	5 (0.8)	14 (8.4)	0 (0.0)	8 (0.8)	11 (5.5)

INTACT, International Assessment of Capacity for Trauma; PIPES, Personnel, Infrastructure, Procedures, Equipment, and Supplies.
* Italicized items are present in both PIPES and INTACT survey instruments.
† Based on 2010 data reporting total and urban population of 788,406 and 167,439, respectively.
‡ Mean per first-level facility only representative of facilities with operating rooms.

DISCUSSION

There is a growing body of literature supporting the need to develop surgical and trauma care systems in LMICs.[1,23] This study aimed to expand on previously gathered countrywide and departmental capacity data from the South American country of Bolivia, providing a more focused and thorough assessment of the surgical and trauma care capacity at health care facilities in the predominantly rural department of Potosí. Our data reveal deficiencies in surgical and trauma care capacity in rural regions of Bolivia, particularly with personnel, which were not as evident in previous assessments. Additionally, our results offer several areas in which to focus future training, as determined by personnel across the department of Potosí.

Potosí had lower median PIPES indices at both rural and urban facilities when compared with data from the department of Santa Cruz.[7] Compared with countrywide data presented in LeBrun et al,[6] Potosí had a lower mean number of general surgeons and anesthesiologists at second- and third-level hospitals. Similarly, Potosí had fewer surgeons and anesthesiologists per 100,000 population than the wealthier department of Santa Cruz, particularly when comparing rural Potosí to rural Santa Cruz.[7] Although 14 facilities in Potosí were also staffed with at least 1 surgical subspecialist, inclusion of their numbers would be unlikely to make up for such large differences. With regard to infrastructure, urban Potosí had a larger number of ORs per 100,000 population when compared with urban Santa Cruz. However, with only a fifth of the department's population living in the city of Potosí, this is further evidence of the significant difference in infrastructure between urban and rural areas. Interestingly, there were minimal differences in equipment and supplies availability between urban and rural facilities.

Targeted interventions to improve access to surgical and trauma care should include the district hospital level, which in the case of Bolivia's health care system is the second-level hospital.[3,8,24] Our study also chose to include first-level facilities with an OR, functional or nonfunctional, because the presence of an OR suggests these facilities have the potential to be upgraded to second-level hospitals. A particular focus should be placed on facilities with limited access to higher-level referral hospitals. The department of Potosí is divided into 11 health networks, one of which is the urban city of Potosí. Access is particularly difficult in 4 of the rural health networks—Uyuni, Tupiza, Sacaca, and Ocurí.[12] Facilities in these health networks are an average of 3.5 hours away from the nearest referral hospital. The second-level hospitals in Uyuni and Tupiza

Table 4. Infrastructure Items by Location*,†

Infrastructure Item	Rural No. (%)	Urban No. (%)
Running water	11 (78.6)	6 (100)
External electricity	13 (92.9)	6 (100)
Functioning back-up generator	9 (64.3)	4 (66.7)
Incinerator	2 (14.3)	2 (33.3)
Medical records	12 (85.7)	6 (100)
Emergency department	11 (78.6)	5 (83.3)
Postoperative care unit	6 (42.9)	4 (67)
Intensive care unit (ICU)	0 (0.0)	5 (83.3)
Blood bank	1 (7.1)	1 (16.7)
Lab to test blood and urine	11 (78.6)	5 (83.3)
Functioning X-ray machine	10 (71.4)	5 (83.3)
Functioning ultrasound machine	11 (78.6)	5 (83.3)
Functioning CT scanner	0 (0.0)	2 (33.3)

CT, computed tomography; INTACT, International Assessment of Capacity for Trauma; PIPES, Personnel, Infrastructure, Procedures, Equipment, and Supplies.
* *Italicized* items are present in both the PIPES and INTACT survey instruments; regular text items are only included in PIPES.
† Table does not include Functional Operating Rooms, which is present in the infrastructure section of PIPES.

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Table 5. Procedures Performed by Location[*,†]

Type of Surgery	Procedure Item	Rural No. (%)	Urban No. (%)
Minor Surgery	*Suturing*	14 (100)	6 (100)
	Wound debridement	12 (85.7)	6 (100)
	Incision and drainage	11 (78.6)	5 (83.3)
Trauma/Resuscitation	*Resuscitation*[‡]	9 (64.3)	6 (100)
	Cricothyroidotomy	5 (35.7)	4 (66.7)
	Tracheostomy	5 (35.7)	3 (50.0)
	Chest tube insertion	5 (35.7)	3 (50.0)
	Burn management	12 (85.7)	6 (100)
	Skin grafting	4 (28.6)	3 (50.0)
	Contracture release	3 (21.4)	1 (16.7)
Orthopedic Trauma	*Splinting*	12 (85.7)	6 (100)
	Casting	11 (78.6)	5 (83.3)
	Traction (closed fracture)	8 (57.1)	5 (83.3)
	Open treatment of fracture	7 (50.0)	5 (83.3)
	Management of osteomyelitis	6 (42.9)	5 (83.3)
	Amputation	7 (50.0)	3 (50.0)
General Surgery—Emergent	Appendectomy	6 (42.9)	5 (83.3)
	Hernia repair—strangulated	6 (42.9)	5 (83.3)
General Surgery—Possibly Emergent	Bowel resection and anastomosis	6 (42.9)	4 (66.7)
	Laparotomy	7 (50.0)	5 (83.3)
	Cholecystectomy	6 (42.9)	5 (83.3)
	Laparoscopic surgery[§]	5 (35.7)	3 (50.0)
General Surgery—Nonemergent	Hernia repair—elective	7 (50.0)	5 (83.3)
Obstetric	Cesarean section	8 (57.1)	5 (83.3)
	Dilatation and curettage	10 (71.4)	5 (83.3)
	Tubal ligation	8 (57.1)	5 (83.3)
	Hysterectomy	7 (50.0)	5 (83.3)
	Obstetric fistula repair	4 (28.6)	5 (83.3)
Pediatric Surgery	Hydrocele repair	5 (35.7)	3 (50.0)
	Male circumcision	6 (42.9)	3 (50.0)
	Pediatric hernia repair	6 (42.9)	4 (66.7)
	Pediatric abdominal wall defect repair	2 (14.3)	2 (33.3)
	Imperforate anus repair	0 (0.0)	3 (50.0)
	Clubfoot repair	1 (7.1)	3 (50.0)
	Cleft lip repair	0 (0.0)	2 (33.3)
Cancer	Biopsy	7 (50.0)	5 (83.3)
Anesthesia	Local/regional anesthesia	12 (85.7)	5 (83.3)
	Spinal anesthesia	8 (57.1)	5 (83.3)
	Ketamine anesthesia	10 (71.4)	4 (66.7)
	General anesthesia	8 (57.1)	5 (83.3)

INTACT, International Assessment of Capacity for Trauma; PIPES, Personnel, Infrastructure, Procedures, Equipment, and Supplies.
* The table presents the number and percentage of rural (n = 14) and urban (n = 6) facilities that responded as consistently being able to perform each procedure. All 40 procedure items are listed, organized into 10 types of surgery as previously described by Henry et al.[22]
† *Italicized* items are present in both the PIPES and INTACT survey instruments; regular text items are only included in PIPES.
‡ Neither PIPES nor INTACT specifies resuscitation type.
§ Author J.L.G.B. states this is an overrepresentation of the number of facilities with the ability to perform laparoscopic surgery.

have the widest catchment area, providing care to a total of 95,045 people across a vast 68,255 km^2 in the southwestern half of the department.[12] The Sacaca and Ocurí health networks in the north are similarly difficult to access, and neither has a functional OR, surgeon, or anesthesiologist.

Recruiting physicians to work in rural facilities is challenging; over 40% of Bolivia's physicians work at

Table 6. Most Common Procedures in Which Training Is Desired, Organized by Facility Level

All Respondents (n = 53)	n (%)	Third-Level Respondents (n = 14)	n (%)	Second-Level Respondents (n = 26)	n (%)	First-Level Respondents (n = 13)	n (%)
Laparoscopic surgery	19 (36%)	Laparoscopic surgery	8 (57%)	Laparoscopic surgery	9 (35%)	C-section/obstetric procedures	5 (38%)
Subspecialist procedures*	11 (21%)	Subspecialist procedures*	4 (29%)	Trauma management†	8 (31%)	Multiple‡	2 (15%)
Trauma management†	10 (19%)	Anesthesia	2 (14%)	Subspecialist procedures*	7 (27%)		

* Includes pediatric surgery, urogynecology, plastic surgery, neurosurgery, esophageal surgery, and surgical oncology.
† Includes trauma management, trauma surgery, resuscitation, and emergency management
‡ Anesthesia, laparoscopic surgery, surgical contraception, and trauma management were each listed by 2 respondents at first-level facilities.

third-level hospitals.[17] Lack of personnel leaves many facilities outfitted with surgical infrastructure, equipment, and supplies, such as the ones in Sacaca and Ocurí, functioning at less than the intended capacity.[6,21] Only one first-level center indicated their OR was used for surgical procedures, with others solely using the space for the occasional vaginal delivery. Only 2 first-level centers had a general surgeon, 1 of whom practiced as a general physician because of the lack of an anesthesiologist. However, lack of personnel was not limited to first-level facilities. The surgeon at one of the second-level hospitals resigned shortly before our assessment, leaving the facility only capable of performing obstetric and gynecologic procedures, which was further limited by an anesthesiologist whose time was split with another facility. At another second-level facility, the surgeon was only there for his 1-year provincial requirement set by the MSD, after which the hospital would likely be without a surgeon on staff.

The MSD and Medical College of Bolivia have a policy requiring those completing a residency to work for 1 year at a provincial hospital before completing their training, a policy that is used in other LMICs.[3,21,25] However, this does not create sustainable access to surgical care, as surgeons often return to larger, urban centers on completing their service. There is also a consistent shortage of residency spots in Bolivia, especially for general surgery and anesthesiology, leaving many medical graduates practicing as general physicians (ie, without residency training).[26] A short-term approach to the lack of personnel at rural facilities could focus on task shifting.[27] With the proper training, it has been found that general physicians can provide local, spinal, and general anesthesia, as well as perform a variety of basic surgical procedures, including appendectomies and hernia repairs.[21] Nurse anesthetists or experienced technicians are another possible resource already used in many LMICs.[27] In Bolivia, however, only anesthesiologists are allowed to administer anesthesia, requiring a change in policy to make this a feasible solution.

For existing personnel, fewer than half of surveyed facilities had personnel trained specifically in trauma management, such as advanced trauma life support training. Second-level facilities should be able to provide procedures such as tracheostomy, cricothyroidotomy, or chest tube placement; however, 2 of the rural, second-level hospitals were not capable. This was due in part to lack of training but also to lack of consistently available equipment and supplies. Nearly a third of respondents queried at second-level hospitals, most of whom were

Table 7. Most Common Procedures in Which Training Is Desired, Organized by Specialty Type

General Surgeons (n = 13)	n (%)	Anesthesiologists (n = 9)	n (%)	OB/GYNs (n = 6)	n (%)	All Other Staff (n = 25)	n (%)
Laparoscopic surgery	9 (69%)	Anesthesia	5 (56%)	Laparoscopic surgery	3 (50%)	C-section/obstetric procedures	5 (20%)
Trauma management*	5 (38%)	Subspecialist procedures†	3 (33%)	Subspecialist procedures†	2 (33%)	Laparoscopic surgery	5 (20%)
Subspecialist procedures†	3 (31%)	Laparoscopic surgery	2 (22%)	Multiple‡	1 (17%)	Trauma management*	4 (16%)

* Includes trauma management, trauma surgery, resuscitation, and emergency management.
† Includes pediatric surgery, urogynecology, plastic surgery, neurosurgery, esophageal surgery, and surgical oncology.
‡ Anesthesia and trauma management were each listed by 1 of the 6 obstetrician-gynecologists (OB/GYNs).

general surgeons, responded they would like further training in trauma management. A number of existing publications describe advanced trauma life support training in LMICs.[28] Additionally, the WHO Emergency and Essential Surgical Care program has been reported to improve trauma management through improving surgical care services in rural areas of LMICs.[29]

A majority of respondents from third-level hospitals, and more than two-thirds of all general surgeon respondents, desired training in laparoscopic surgery. Of the most commonly performed surgeries in the region as reported by survey respondents, cholecystectomy, appendectomy, and hernia repair could all be performed laparoscopically. Both third-level and 6 second-level facilities indicated they were able to perform laparoscopic surgery at the time the surveys were administered. However, 2 of these 8 facilities stated they did not always have access to the necessary equipment, and one of the authors believed these data overestimate the number of facilities capable of performing laparoscopic surgery. A number of publications have described the implementation of laparoscopic surgery in LMICs, including Bolivia.[30,31] Given the limited surgical capacity in the department of Potosí, however, a focus on laparoscopic surgery should be limited to third-level hospitals, with primary efforts focusing on developing access to basic surgical and trauma care in rural areas.

There are a number of limitations in this study. PIPES and INTACT were designed to be efficient, easy-to-implement assessments. Data are based on the responses from individual personnel, without confirmation by direct inspection or surgical logs. Additionally, neither survey instrument suggests differing standards for item availability based on facility level. Two survey items were incorrectly translated: running water and oxygen concentrator. Oxygen concentrator was removed from the analysis, whereas running water, mistranslated as potable running water, was not removed because the mistranslation did not appear to affect responses. With regard to the short-answer questions, respondents were chosen based on availability and not the representativeness of the sample. Additionally, responses to short-answer questions were subjective, and most commonly performed procedures were not confirmed with surgical logs.

CONCLUSION

The present study builds on previously collected countrywide data to offer a more focused assessment of surgical and trauma care capacity in the Bolivian department of Potosí using a combined PIPES and INTACT assessment tool. Capacity weaknesses were most notable at first- and second-level facilities in rural Potosí, particularly with personnel. By contrasting with previous assessments conducted in Bolivia, our data demonstrate countrywide data have the potential to overestimate surgical capacity of poorer, less developed regions of LMICs.

Efforts to increase surgical and trauma capacity should focus on increasing the number of surgical personnel, especially in the rural health networks with most limited access to referral facilities. Training of existing personnel should include trauma management at first- and second-level facilities and, potentially, laparoscopic surgery at third-level facilities. Data gathered from these assessments have been made available to SEDES Potosí, with the potential to inform interventions to improve surgical and trauma care access across the department.

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