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One-day point prevalence of healthcare-associated infections and antimicrobial use in four countries in Latin America

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ABSTRACT

Background and aims: Experience in the region shows that in some countries there is very good surveillance of Healthcare-associated infections (HAIs) in health services, but there is no national data consistently in all countries. Therefore, we set to estimate the total burden of HAIs and antimicrobial use in acute care hospitals in Brazil, Venezuela, Mexico, and Colombia using the one-day point prevalence methodology.

Methods: The survey was conducted between June and July 2016. In each ward or unit, HAIs and antimicrobial use data were collected on a single day by a trained team of researchers. Also, for each patient, we collected data on risk factors for infections.

Results: One out of ten individuals surveyed had at least one healthcare-associated infection (HAI). Pneumonia and surgical site infections were the most relevant among the surveyed countries. Most of the surveyed participants, regardless of their HAI status, received antibiotics except the individuals managed in Brazil. Carbapenems and third-generation Cephalosporins were among the most frequently used antibiotics.

Conclusion: Our results add to WHO's recent efforts to understand HAIs prevalence and antibiotic consumption in low and middle-income countries, of which we studied three that were not included in their last report.

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Introduction

Healthcare-Associated Infections (HAI) appear 48 h following the admission of a patient to a hospital or within 30 days after their discharge from a healthcare facility (Revelas, 2012). HAIs are unrelated to the original illness that brings patients to hospitals, neither are they the result of an infectious agent carried by the

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patient at the time of admission (Sydnor and Perl, 2011). Although modern medicine has devised mechanisms to prevent and treat HAIs, nosocomial infections continue to represent a challenge for 21st-century medicine (Salvatierra-Gonzalez, 2003). In fact, surveillance of HAI has become increasingly complex due recent changes (PAHO, 2012). For instance, hospitals house a larger number of patients with debilitated immune systems. Moreover, other barriers to appropriate management of HAIs include; medical procedures that bypass the body's natural protective barriers, medical staff moving from patient to patient thus providing a way for pathogens to spread, inadequate sanitation protocols regarding uniforms equipment sterilization, washing and other preventive measures that may either be unheeded by hospital personnel or too lax to sufficiently isolate patients from infectious agents. Finally, as recently reported by the World Health Organization "the efficacy of commonly used antibiotics is threatened by antimicrobial resistance among pathogens" (WHO, 2019). Because the routine use of antimicrobial agents in hospitals creates selection pressure for the emergence of the resistant strains of microorganisms, it is a priority to monitor their consumption through proper surveillance systems that apply a valid and reproducible methodology (WHO, 2019).

HAI surveillance is complex and requires the use of standardized criteria, availability of diagnostic facilities and expertise to conduct it and interpret the results. In addition, the definition of HAI changes in time and location, thus representing a challenge for proper epidemiologic surveillance. Surveillance systems for HAI exist in several high-income countries, but are virtually nonexistent in most low- and middle-income countries (WHO, 2011). Although Latin America has the highest prevalence of HAI (Versporten et al., 2018), there is a paucity of information in the region. Cross-sectional studies like one-day prevalence have been suggested as an alternative for costly surveillance mechanisms. Although previous reports in Latin American countries consider HAI, they oversee the use of antibiotics or do not consider diverse locations or settings. Furthermore, they usually have ecological designs, failing to gather patient-level data (WHO, 2019).

Therefore, we set to estimate the total burden of healthcare-associated infections (HAI) and antimicrobial use in acute care hospitals in Brazil, Venezuela, Mexico, and Colombia using the one-day point prevalence methodology.

Methodology

We defined an active infection when signs and symptoms were present or when the patient was receiving treatment for that infection (as to the study approved protocol and according to Revelas A, 2012) (Revelas, 2012) on the survey date.

All acute care hospitals in the studied countries proposed to participate were eligible for the survey according to the approved protocol.

The hospitals participating in the study are shown in detail in Table 1. We included all acute care wards in acute care facilities (e.g. acute psychiatric wards and neonatal ICUs are included). The ones excluded are: (a) long-term care wards in acute care facilities (e.g. nursing homes, spinal injury care); (b) trauma and emergency departments (except for wards attached to A&E departments where patients are monitored for more than 24 h). The ward specialty was always recorded so that results can be stratified and standardized. All patients admitted to the ward before or at 8 a.m. and not discharged at the time of the survey were included. We included long-term care patients in acute care wards unless more than 20% of the patients in the acute care ward were long-term care patients.

The survey was conducted between June and July 2016. For each ward or unit, the data was collected on a single day. The total time frame for data collection for all wards of a single hospital should not have exceeded two to three weeks. Surveys were completed from Mondays through Fridays except for the wards that carried out elective procedures. These were surveyed between Tuesday and Friday since fewer patients are scheduled for elective procedures on Mondays.

The data was collected at national, hospital and patient level. For each hospital, we investigated the type and size of the facilities and the average length of stay. The hospitals were classified as primary (general hospitals without many specialties), secondary (takes referrals from general hospitals and has some specialties), tertiary (takes referrals from primary and secondary clinics) and specialized (single clinical specialty). For every patient, we collected certain risk factors for HAIs. The risk factors for HAI that were considered, and therefore collected in the study were: age group, length of hospital stay, surgical procedures since hospital admission, McCabe score, and use of invasive devices. According to WHO and the Global-PPS (World Health Organization; The Global Point Prevalence Survey), these are the majority of the most common factors independently associated with HAI occurrence in acute-care settings, both, in high-income and in low- and middle-income countries (WHO, 2011; Versporten et al., 2018). Additional data was collected from those patients that matched the definition of active HAI and/or those receiving antimicrobial agents.

At the patient level, the data was collected by a group of associated clinical investigators (nurses, interns and resident doctors, who were collaborators during the study time, in the local Infection Control and / or Antimicrobial Management Teams of each participant hospital), which was coordinated by a specialist

Table 1
Characteristics of surveyed hospitals.

Country	Hospital	Hospital size (total number of beds)	Number of acute care beds	Number of ICU beds	Hospital type
Brazil	Hospital Moinhos de Vento	372	322	40	Tertiary
	Hospital Santa Casa de Misericordia	449	307	73	Tertiary
	Hospital Das Clinicas	547	453	84	Tertiary
Colombia	Fundacion Valle de Lili	514	148	80	Tertiary
	Hospital Universitario San Ignacio	388	388	32	Tertiary
Mexico	Antiguo Hospital Civil de Guadalajara "Fray Antonio Alcalde"	964	843	59	Tertiary
	Hospital General Dr. Manuel Gea González	307	178	8	Tertiary
	Hospital Hospital Universitario "Dr. José Eleuterio González"	596	455	42	Tertiary
	Hospital Infantil de México Federico Gómez	349	229	42	Specialized
Venezuela	Centro Médico de Caracas	164	93	16	Tertiary
	Hospital Universitario de Caracas	1,200	934	26	Tertiary

MD [internist and/or infectologist]). The Links and Links team made available training materials for the associate researchers that collected the data, and for the hospital project coordinator as well, which consisted of printed material and a one-day course. The data collectors received training and were advised to request clarification from their hospital project coordinator (specialized MD) if the information contained in the records was not clear to them. We built a specific form of electronic data collection with standard structured fields, which were used in all participating hospitals. Data was extracted from a number of sources available on the ward at the time of the survey. These included: nursing notes, medical notes, temperature charts, drug charts, electronic prescribing systems, surgical notes, laboratory reports (e.g. microbiology results), and other relevant charts (e.g. wound charts, stool charts, care plans). The McCabe score (Reilly et al., 2016) was calculated for each participant.

After the survey forms were filled in, research team coordinators verified the information and entered it in the PPS Computer system. All the data was submitted to the L & L Data warehouse in Mexico City for the final processing.

In the present investigation, the codes list and case definitions of HAIs used corresponded to the codebook of the European Center for Disease Prevention and Control (ECDC) (European Centre for Disease Prevention and Control, 2012).

The mean and the standard deviation of the continuous variables was computed when they followed a normal distribution. We reported the median and the 95% confidence intervals of continuous variables that did not follow a normal distribution. For categorical variables, we computed contingency tables with frequencies to describe the distribution of the observation for each country and hospital.

The study protocol incorporates several methodological elements of the Point prevalence survey of healthcare associated infections and antimicrobial use in European acute care hospitals from the ECDC (European Centre for Disease Prevention and Control, 2012). The protocol was submitted and approved by the corresponding ethics committee of each hospital.

Results

On average, 11.50% (10.37%-12.77%) of the participants surveyed had at least one HAI, with Venezuela being the country with the highest proportion of HAIs and Brazil the lowest Table 2.

Pneumonia was the most common HAI in general, with positive microbiological data in 48.6% of the cases; surgical site infection was the second most prevalent, followed by urinary tract infection, of which 80.6% had microbiological confirmation. The fourth most frequent HAI was bloodstream infection (laboratory confirmed, by source of BSI), of which 34.5% originated in a central vascular catheter. On the other hand, gastro-intestinal system infections corresponded to the fifth most frequent HAI, being C. difficile infection 30.3% of them Table 3.

The countries with the highest pneumonia rate were Mexico (58.3% with positive microbiology) and Venezuela (47.4% with positive microbiology). Colombia was the country with the lowest rate of pneumonia, but with 83.3% of the cases without positive microbiological results. On the other hand, Colombia and Mexico were the countries that reported higher rates of bloodstream infection, Venezuela being the country with the lowest rate. Mexico had the highest rate of urinary tract infection and infections of the gastrointestinal system, while Brazil reported the lowest rate in both. Venezuela showed the highest rates for surgical site infection, central vascular catheter-related infection, and neonate infections, with Brazil being the country with the lowest rates in these three HAIs Table 3.

Regarding the total prevalence of HAIs, the highest was found in Venezuela (17.97%), with Brazil being the one that showed the lowest (7.23%), with an average for the four countries of 12.26% (Colombia 11.40%, Mexico 13.24 %) Table 3.

Of the total cases of HAI, 42% presented positive microbiological results. The main group of microorganisms isolated was that of Enterobacteriaceae (41.4%), followed by gram-positive cocci (22%), gram-negative bacilli non-Enterobacteriaceae (19.8%), fungi (10.6%), anaerobic bacilli (4%), gram-positive bacilli (1.3%), other bacteria (0.4%), and viruses (0.4%) Table 4.

The specific microorganisms most frequently identified, considering the total isolates of the study were Escherichia coli (6.6%), Klebsiella pneumoniae (6.4%), Staphylococcus aureus (4.7%), Pseudomonas aeruginosa (3.5%), Acinetobacter baumannii (3.3%), Clostridium difficile (1.7%), Enterobacter cloacae (1.6%), Candida albicans (1.4%), Enterococcus faecalis (1.2%), Enterobacter sp (1.2%), and Candida sp., Not specified (1.2%) Table 4.

Considering the different groups of microorganisms, and within these the most frequently isolated microorganisms, we found that Colombia was the country with the largest presence of Enterobacteriaceae (56.4%), and Mexico had the lowest report among the isolates during the study (36.0%), however, together with Venezuela, they showed the highest presence of Escherichia coli (Mexico 18.6%, Venezuela 19.0%). Regarding gram-negative bacilli, non-Enterobacteriaceae, Mexico had the highest report (30.2%) and Colombia the lowest (10.3%). Specifically, from Pseudomonas aeruginosa, Mexico (11.6%) and Venezuela (10.3%) showed the highest rates, while Brazil (2.3%) and Colombia (2.6%) had the lowest. Brazil (34.1%) and Venezuela (29.3%) had the highest rates of gram-positive cocci, with Mexico having the lowest figure (11.6%). Particularly with Staphylococcus aureus, Brazil exhibited the highest rate with 25.0%, while Mexico showed a rate of 3.5%. In relation to Candida in general, Mexico had the highest figure (12.8%) and Venezuela the lowest (5.2%). Especially from C. albicans, Colombia is the country with the highest report (5.1%). It is noteworthy that Venezuela did not report isolates of this microorganism Table 4.

Of the total number of patients analyzed (2,740), 49.49% (47.62%-62.69%) had at least one antimicrobial agent at the time of the study. The highest use of antimicrobial agents corresponded to Mexico (59.31% [56.33%-62.29%]) and Venezuela (56.26% [52.12%-60.40%]), Brazil being the country with less use in the sample analyzed (29.43% [26.20%-32.67%]) Table 5.

Regarding the indications for use of antimicrobial agents in the sample analyzed by participating country, Mexico, which was the country with the highest use of antimicrobials, showed a very similar specific use for community-acquired infections (30.0%) and for HAIs (29.2%), use being indicated in a smaller proportion for patients with long term care facility acquired infections (16.1%),

Table 2
Prevalence of at least one Healthcare-associated infections by country.

Country	Brazil	Colombia	Mexico	Venezuela	Total
Patients	761	386	1,042	551	2,740
Patients with at least one HAI	54	42	121	98	315
Prevalence of at least one HAI (%; IC 95%)	7.10 (5.27-8.92)	10.88 (7.77-13.99)	11.61 (9.67-13.56)	17.79 (14.59-20.98)	11.50 (10.37-12.77)

Table 3
Prevalence of Total Healthcare-associated infections by country.

HAI	Brazil %	Colombia %	Mexico %	Venezuela %	Total %
Peripheral vascular catheter-related infection	0.26	0.00	0.10	1.45	0.40
CRI1-PVC Local PVC-related infection (no positive blood culture)	0.00	0.00	0.00	0.54	0.11
CRI2-PVC General PVC-related infection (no positive blood culture)	0.00	0.00	0.00	0.91	0.18
CRI3-PVC Microbiologically confirmed PVC-related BSI	0.26	0.00	0.10	0.00	0.11
Bone and joint infections	0.00	0.26	0.00	1.09	0.26
HA-ART Articulación o bolsa sinovial	0.00	0.00	0.00	0.36	0.07
BJ-BONE Osteomyelitis	0.00	0.26	0.00	0.73	0.18
Eye, Ear, Nose or Mouth Infection	0.13	0.00	0.10	0.36	0.15
EENT-CONJ Conjunctivitis	0.00	0.00	0.10	0.00	0.04
EENT-ORAL Oral cavity (mouth, tongue, or gums)	0.13	0.00	0.00	0.18	0.07
EENT-EAR Ear, mastoid	0.00	0.00	0.00	0.18	0.04
Skin and soft tissue infections	0.00	1.04	0.77	2.00	0.84
SST-ST Soft tissue	0.00	1.04	0.38	0.36	0.36
SST-DECU Decubitus ulcer	0.00	0.00	0.00	0.91	0.18
SST-BURN Burn	0.00	0.00	0.10	0.00	0.04
SST-SKIN Skin infection	0.00	0.00	0.29	0.73	0.26
Cardiovascular system infections	0.00	0.52	0.00	1.27	0.33
CVS-ENDO Endocarditis	0.00	0.26	0.00	1.09	0.26
CVS-VASC Arterial or venous infection	0.00	0.26	0.00	0.18	0.07
Gastro-intestinal system infections	0.26	1.30	1.92	1.09	1.20
GI-IAB Intraabdominal infection, not specified elsewhere	0.26	0.52	0.58	1.09	0.58
GI-CDI Clostridium difficile infection	0.00	0.52	0.77	0.00	0.36
GI-GE Gastroenteritis (excluding CDI)	0.00	0.00	0.58	0.00	0.22
GI-GIT Gastrointestinal tract, excl. GE, CDI	0.00	0.26	0.00	0.00	0.04
Central nervous system infections	0.53	0.00	0.29	0.00	0.26
CNS-IC Intracranial infection	0.13	0.00	0.19	0.00	0.11
CNS-MEN Meningitis or ventriculitis	0.39	0.00	0.10	0.00	0.15
Bloodstream infections (laboratory confirmed, by source of BSI)	1.31	1.55	1.44	0.54	1.24
BSI UNK No information/truly unknown	0.13	0.00	0.29	0.00	0.15
BSI C-CVC Central vascular catheter	0.79	0.52	0.38	0.00	0.44
BSI C-PVC Peripheral vascular	0.13	0.00	0.00	0.00	0.04
BSI UO Bloodstream infection of confirmed unknown origin	0.00	0.78	0.48	0.00	0.29
BSI S-DIG Secondary to digestive tract infection	0.00	0.00	0.29	0.18	0.15
BSI-SSI Secondary to surgical site infection	0.13	0.00	0.00	0.00	0.04
BSI S-UTI Secondary to urinary tract infection	0.00	0.00%	0.00	0.18	0.04
BSI S-OTH Secondary to another infection	0.13	0.00	0.00	0.00	0.04
BSI S-SST Secondary to skin and soft tissue infection	0.00	0.00	0.00	0.18	0.04
BSI S-PUL Secondary to pulmonary infection	0.00	0.26	0.00	0.00	0.04
Reproductive tract infections	0.00	0.00	0.00	0.54	0.11
REPR-EMET Endometritis	0.00	0.00	0.00	0.54	0.11
Lower respiratory tract infection (other than pneumonia)	0.26	0.00	0.10	0.00	0.11
LRI-BRON Bronchitis, tracheobronchitis, etc. Without evidence of pneumonia	0.13	0.00	0.00	0.00	0.04
LRI-LUNG Other infections of the lower respiratory tract	0.13	0.00	0.10	0.00	0.07
Urinary tract infections	0.79	1.55	1.73	1.09	1.31
UTI-A Symptomatic urinary tract infection, microbiologically confirmed	0.79	1.30	1.44	0.54	1.06
UTI-B Symptomatic urinary tract infection, not microbiologically confirmed	0.00	0.26	0.29	0.54	0.26
Surgical site infections	0.66	1.81	1.82	2.00	1.53
SSI-O Surgical site infection, Organ/Space	0.39	1.81	0.29	0.36	0.55
SSI-D Surgical site infection, Deep incisional	0.26	0.00	0.67	0.73	0.47
SSI-S Surgical site infection, Superficial incisional	0.00	0.00	0.86	0.91	0.51
Neonates infections	0.26	0.00	0.19	1.27	0.40
NEO-LCBI Laboratory-confirmed bloodstream infection with non- coagulase-negative staphylococci in neonates	0.00	0.00	0.00	0.18	0.04
NEO-PNEU Pneumonia in neonates	0.26	0.00	0.00	0.36	0.15
NEO-CSEP Clinical sepsis in neonates	0.00	0.00	0.19	0.73	0.22
Central vascular catheter-related infection	0.79	1.04	0.96	1.45	1.02
CRI3-CVC Microbiologically confirmed CVC-related BSI	0.79	0.78	0.67	0.73	0.73
CRI1-CVC Local CVC-related infection (no positive blood culture)	0.00	0.26	0.29	0.18	0.18
CRI2-CVC General CVC-related infection (no positive blood culture)	0.00	0.00	0.00	0.54	0.11
Systemic (Generalized) infections	0.26	0.00	0.29	0.18	0.22
SYS-CSEP Clinical sepsis in adults and children	0.26	0.00	0.19	0.18	0.18
SYS-DI Disseminated infection	0.00	0.00	0.10	0.00	0.04
Pneumonia	1.71	1.55	3.45	3.45	2.70
PN1 Pneumonia, positive quantitative culture, minimally contaminated LRT specimen	0.00	0.00	1.73	0.00	0.66
PN5 Pneumonia - Clinical signs of pneumonia without positive microbiology	1.05	1.30	1.44	1.81	1.39
PN3 Pneumonia, microbiological diagnosis by alternative microbiology methods	0.66	0.26	0.10	0.73	0.40
PN4 Pneumonia, pos. sputum culture or non-quantitative culture, LRT specimen	0.00	0.00	0.19	0.36	0.15
PN2 Pneumonia, positive quantitative culture, possibly contaminated LRT specimen	0.00	0.00	0.00	0.54	0.11
Other origin/unknown	0.00	0.78	0.10	0.18	0.18
Others	0.00	0.78	0.10	0.18	0.18
Total	7.23	11.40	13.24	17.97	12.26

Table 4
Microorganisms isolated in Healthcare-associated infections by country.

Type of microorganisms isolated in HAIs	Brazil %	Colombia %	Mexico %	Venezuela %	Total %
Gram-positive cocci	34.1	20.5	11.6	29.3	22.0
Staphylococcus aureus	25.0	5.1	3.5	13.8	10.6
Staphylococcus epidermidis	0.0	2.6	2.3	3.4	2.2
Staphylococcus haemolyticus	2.3	0.0	0.0	0.0	0.4
Coagulase-negative stafylococci, not specified	0.0	0.0	0.0	3.4	0.9
Other coagulase-negative stafylococci (CNS)	0.0	0.0	3.5	0.0	1.3
Staphylococcus sp., not specified	4.5	2.6	0.0	0.0	1.3
Streptococcus pneumoniae	0.0	2.6	0.0	0.0	0.4
Streptococcus agalactiae (B)	0.0	0.0	0.0	1.7	0.4
Streptococcus sp., other	0.0	0.0	0.0	3.4	0.9
Enterococcus faecalis	2.3	5.1	1.2	3.4	2.6
Enterococcus faecium	0.0	0.0	1.2	0.0	0.4
Enterococcus sp., other	0.0	2.6	0.0	0.0	0.4
Gram-positive bacilli	2.3	0.0	0.0	3.4	1.3
Corynebacterium species	2.3	0.0	0.0	0.0	0.4
Other gram-positive bacilli	0.0	0.0	0.0	3.4	0.9
Enterobacteriaceae	40.9	56.4	36.0	39.7	41.4
Citrobacter freundii	0.0	0.0	0.0	1.7	0.4
Enterobacter cloacae	6.8	7.7	1.2	1.7	3.5
Enterobacter aerogenes	0.0	0.0	0.0	1.7	0.4
Enterobacter agglomerans	0.0	2.6	0.0	0.0	0.4
Enterobacter sp., other	0.0	10.3	2.3	0.0	2.6
Enterobacter sp., not specified	2.3	0.0	0.0	0.0	0.4
Escherichia coli	6.8	10.3	18.6	19.0	15.0
Klebsiella pneumoniae	13.6	23.1	11.6	13.8	14.5
Proteus mirabilis	6.8	2.6	1.2	0.0	2.2
Serratia marcescens	0.0	0.0	1.2	0.0	0.4
Morganella species	4.5	0.0	0.0	0.0	0.9
Other enterobacteriaceae	0.0	0.0	0.0	1.7	0.4
Gram-negative bacili, non-enterobacteriaceae	11.4	10.3	30.2	17.2	19.8
Acinetobacter baumannii	9.1	0.0	12.8	3.4	7.5
Acinetobacter calcoaceticus	0.0	0.0	1.2	0.0	0.4
Pseudomonas aeruginosa	2.3	2.6	11.6	10.3	7.9
Stenotrophomonas maltophilia	0.0	2.6	2.3	0.0	1.3
Burkholderia cepacia	0.0	2.6	0.0	3.4	1.3
Haemophilus influenzae	0.0	2.6	0.0	0.0	0.4
Legionella species	0.0	0.0	2.3	0.0	0.9
Anaerobic bacilli	0.0	5.1	8.1	0.0	4.0
Clostridium difficile	0.0	5.1	8.1	0.0	4.0
Other bacteria	0.0	0.0	0.0	1.7	0.4
Mycobacterium, atypical	0.0	0.0	0.0	1.7	0.4
Fungi	11.4	7.7	12.8	8.6	10.6
Candida albicans	2.3	5.1	4.7	0.0	3.1
Candida parapsilosis	4.5	0.0	0.0	1.7	1.3
Candida tropicalis	0.0	0.0	0.0	1.7	0.4
Candida sp., other	0.0	0.0	3.5	1.7	1.8
Candida sp., not specified	2.3	2.6	4.7	0.0	2.6
Fungi other	2.3	0.0	0.0	3.4	1.3
Virus	0.0	0.0	1.2	0.0	0.4
Rhinovirus	0.0	0.0	1.2	0.0	0.4
Negative codes	0.0	0.0	11.6	22.4	10.1
Microorganism not identified	0.0	0.0	4.7	0.0	1.8
Examination not done	0.0	0.0	1.2	1.7	0.9
Result not yet available or missing	0.0	0.0	1.2	20.7	5.7
Microorganism not identified	0.0	0.0	4.7	0.0	1.8

Table 5
Prevalence of patients with at least one antimicrobial by country.

Country	Patients	Patients with at least one antimicrobial agent	
		n	%
Brazil	761	224	29.43 (26.20-32.67)
Colombia	386	204	52.85 (47.48-57.83)
México	1,042	618	59.31 (56.33-62.29)
Venezuela	551	310	56.26 (52.12-60.40)
Total	2,740	1,356	49.49 (47.62-62.29)

surgical prophylaxis (13.3%), and medical prophylaxis (11.4%) respectively. In Venezuela, the country with the second highest antimicrobial agents use, indications were as follows: community acquired infections (32.8%), long term care facility acquired infections (25.4%), HAIs (19.8%), surgical prophylaxis (11.1%) and medical prophylaxis (10.9%). In Colombia, the indications were for: community acquired infections (58.1%), HAIs (20.5%), long term care facility acquired infections (14.1%), surgical prophylaxis (4.1%) and medical prophylaxis (2.7%). For its part, in Brazil, which was the country with the least use of antimicrobial agents, the registry was as follows: HAIs (44.6%), community-acquired infections (38.3%), medical prophylaxis (9.0%), long term care facility acquired infections (6.9%), and surgical prophylaxis (1.2%) respectively Table 6. Regarding the route of administration of antimicrobials, 88.56% were parenteral, 11.39% oral, 0.05% a minimum rectally, and the inhaled route was not used. These values are practically the same when analyzing country by country.

An important point to be noted was the low registration of antimicrobial agents' indication of use in the notes within patients'

Table 6
Antimicrobial indication by country.

Country	Total number of antimicrobial agents	HAI prevalence %	Reason for use in patient's chart %	Medical prophylaxis %	Surgical prophylaxis %	Community-acquired infection %	HAI %	Long term care Facility acquired infection %
Brazil	334	7.2	85.3	9.0	1.2	38.3	44.6	6.9
Colombia	365	11.4	57.0	2.7	4.1	58.1	20.5	14.1
Mexico	1,364	13.2	39.1	11.4	13.3	30.0	29.2	16.1
Venezuela	677	17.9	29.2	10.9	11.1	32.8	19.8	25.4

medical records. In Venezuela, the registration in the chart was only 29.2%, in Mexico 39.1%, while in Colombia it was 57.0%. Brazil stands out because it had a registration rate of antimicrobial use indication in 85.3% of the medical records of the patients analyzed in the study Table 6.

Mexico and Venezuela were the countries that most frequently used antibiotics in general. Compared to Brazil, Venezuela used antibiotics twice as frequently, and Mexico four times more frequently Table 6.

Carbapenems were the most commonly used antibiotics in Brazil. In Colombia, Carbapenems were only surpassed in terms of utilization by penicillin used in combination with beta-lactamase inhibitors. The use of carbapenems in Mexico was second only to third generation cephalosporins, which were also the most commonly used antibiotics in Venezuela Table 7.

Regarding the use of specific antimicrobials in HAIs, in Brazil the most used were Meropenem and Vancomycin, and the HAI groups with the highest use of antimicrobial agents were pneumonia and bloodstream infections. In Colombia, the pattern was similar but with greater use of Meropenem, with bloodstream infections being the main diagnosis, followed by urinary tract infection. In Mexico, the use was similar. The main HAIs were pneumonia and surgical site infections. In Venezuela, the use of vancomycin was slightly higher than that of Meropenem, with pneumonia and neonate infections being the main HAIs in relation to the use of antimicrobials Table 8.

As to the risk factors for HAI registered and analyzed in this study, we found that Brazil was the country with the highest proportion of patients with ≥70 years of age (25%), with Mexico as the lowest proportion (11.9%); as for LOS > 7 days, Venezuela registered 74.7%, compared to Brazil and Mexico, with around 40%. In Brazil 46.1% had undergone surgery since hospitalization, Venezuela being the one with the least number of surgeries performed since the hospitalization (24.4%). As to McCabe's score of ultimately and rapidly fatal, Colombia and Mexico had in this classification approximately 30% of their studied population, Brazil being the one that showed a lower population proportion in this risk group (11.2%). Regarding the use of invasive devices such as

Table 7
Prevalence of antibiotic use by country.

Antibiotic group	Brazil	Colombia	Mexico	Venezuela	Total
Intraluminal agents for gastrointestinal diseases	0.13%	0.26%	1.73%	0.36%	0.80%
Tetracyclines	0.53%	1.81%	1.92%	0.00%	1.13%
Penicillins of extended spectrum with no pseudomonas activity	5.26%	3.11%	1.54%	3.81%	3.25%
Beta-lactamase sensitive Penicillin	0.00%	0.52%	0.48%	0.00%	0.26%
Beta-lactamase resistant Penicillins	1.05%	2.59%	1.15%	2.00%	1.50%
Beta-lactamase inhibitors	2.10%	0.00%	0.29%	0.00%	0.69%
Combinations of penicillin with beta-lactamase inhibitors	1.58%	16.58%	2.50%	1.81%	4.09%
First generation Cephalosporins	3.02%	4.66%	8.35%	8.35%	6.35%
Second generation Cephalosporins	3.02%	0.00%	0.19%	0.00%	0.91%
Third generation Cephalosporins	0.92%	2.85%	17.85%	16.33%	10.73%
Other Cephalosporins	2.10%	3.37%	2.78%	0.91%	2.30%
Monobactams	0.13%	0.00%	0.00%	0.91%	0.22%
Carbapenems	6.31%	16.06%	12.86%	12.16%	11.35%
Other penems and cephalosporins	0.00%	0.26%	0.00%	0.00%	0.04%
Trimethoprim and derivatives	0.00%	0.78%	0.10%	1.81%	0.51%
Intermediate action Sulfonamides	0.00%	0.26%	0.10%	0.00%	0.07%
Prolonged action Sulfonamides	0.00%	0.00%	0.29%	0.00%	0.11%
Sulfonamide and trimethoprim combination, including derivatives	0.79%	0.52%	2.40%	1.09%	1.42%
Macrolides	1.45%	2.85%	1.63%	0.73%	1.57%
Lincosamides	0.53%	1.30%	4.51%	2.18%	2.48%
Streptomycines	0.00%	0.00%	0.10%	0.00%	0.04%
Aminoglycosides	2.76%	1.81%	5.18%	6.35%	4.27%
Fluoroquinolones	2.37%	2.59%	3.36%	4.36%	3.18%
Antibacterial combination	0.00%	0.00%	0.00%	0.18%	0.04%
Glycopeptide antibiotics	5.39%	6.48%	7.29%	15.43%	8.28%
Polymyxins	2.23%	2.59%	0.58%	0.54%	1.31%
Parenteral metronidazole	0.39%	1.04%	7.01%	5.81%	4.09%
Other antibiotics	0.13%	3.63%	2.88%	1.09%	1.86%
Amphotericin B	0.26%	0.26%	0.96%	1.45%	0.77%
Miconazole	0.00%	0.00%	0.10%	0.00%	0.04%
Triazole derivatives	0.79%	5.18%	2.30%	6.17%	3.07%
Other systemic antimycotics	0.13%	2.33%	0.48%	0.00%	0.55%
Antibiotic with antimycobacterial activity	0.13%	1.04%	2.59%	0.73%	1.31%
Hydracids	0.00%	0.52%	1.63%	0.54%	0.80%
Other drugs to treat tuberculosis	0.00%	1.04%	3.07%	0.54%	1.42%
Nitroimidazole derivatives	0.26%	1.30%	1.25%	0.18%	0.77%
Total	43.76%	87.56%	99.42%	95.83%	81.57%

Table 8
Main antimicrobial agents used in HAIs and Group of HAI's where antimicrobials are mostly used by Country.

Brazil	
Main antimicrobial agents used in HAIs	
Meropenem	19.60%
Vancomycin (parenteral)	15.90%
Polymyxin B	10.30%
Amikacin	8.40%
Ertapenem	7.50%
Oxacillin	4.70%
Cefuroxime	4.70%
Others	29.00%
Total	100.00%
Group of HAI's where antimicrobials are mostly used	
Pneumonia	26.20%
Bloodstream infections (laboratory confirmed, by source of BSI)	26.20%
Urinary tract infections	9.30%
Central vascular catheter-related infections	9.30%
Others	29.00%
Total	100.00%
Colombia	
Main antimicrobial agents used in HAIs	
Meropenem	20.50%
Vancomycin (parenteral)	9.60%
Ceftriaxone	6.00%
Piperacillin and enzyme inhibitor	4.80%
Fluconazole	4.80%
Ampicillin and enzyme inhibitor	3.60%
Cefepime	3.60%
Colistin (injection, infusion)	3.60%
Polymyxin B	3.60%
Caspofungin	3.60%
Tigecycline	2.40%
Ampicillin (oral)	2.40%
Cefazolin	2.40%
Others	28.90%
Total	100.00%
Group of HAI's where antimicrobials are mostly used	
Bloodstream infections (laboratory confirmed, by source of BSI)	19.30%
Urinary tract infections	12.00%
Surgical site infections	12.00%
Central vascular catheter-related infections	12.00%
Pneumonia	10.80%
Gastro-intestinal system infections	9.60%
Others	24.10%
Total	100.00%
Mexico	
Main antimicrobial agents used in HAIs	
Meropenem	17.60%
Vancomycin (parenteral)	11.00%
Tigecycline	5.70%
Metronidazole (parenteral)	5.70%
Ertapenem	3.80%
Linezolid	3.80%
Rifampicin	3.80%
Ceftriaxone	3.30%
Cefepime	3.30%
Amikacin	3.30%
Fluconazole	3.30%
Vancomycin (oral)	2.90%
Metronidazole (oral, rectal)	2.90%
Others	29.50%
Total	100.00%
Group of HAI's where antimicrobials are mostly used	
Pneumonia	33.80%
Surgical site infections	18.10%
Gastro-intestinal system infections	11.40%
Bloodstream infections (laboratory confirmed, by source of BSI)	9.00%
Others	27.60%
Total	100.00%
Venezuela	
Main antimicrobial agents used in HAIs	
Vancomycin (parenteral)	20.90%
Meropenem	19.30%
Ceftriaxone	8.60%
Amikacine	8.00%
Fluconazole	8.00%
Metronidazole (parenteral)	4.80%
Ampicillin, combinations (oral, parenteral)	3.20%
Others	27.30%
Total	100.00%
Group of HAI's where antimicrobials are mostly used	
Pneumonia	20.90%
Neonates infections	12.30%
Surgical site infections	11.80%
Skin and soft tissue infections	8.60%
Cardiovascular system infections	8.00%
Peripheral vascular catheter-related infection	7.00%
Gastro-intestinal system infections	7.00%
Others	24.60%
Total	100.00%

central vein catheter (CVC), urinary catheter and intubation, Colombia showed use in 65% of its studied population, Venezuela being the country with the lowest use (27.2%) Table 9.

The average age among the 2,740 individuals surveyed was 41 years of age and the proportion of female participants was 47%. Around 28% of the participants were surveyed in Brazilian institutions, 14% in Colombian hospitals, 38% in Mexican and 20% in Venezuelan Table 9.

Discussion

We conducted a one-day prevalence study of healthcare-associated infections that included 11 acute care facilities located in four Latin American countries, along with a study of the pattern of antimicrobial use. It is important to mention that the authors decided to use in the present investigation the code list and case definitions of HAIs that correspond to the codebook of the European Center for Disease Prevention and Control (ECDC), which is broader than that commonly used in the English-speaking world (CAUTI, CLABSI, etc.). This was in order to capture the highest number of HAIs at the time of the study; additionally, the study protocol incorporates several methodological elements of the Point prevalence survey of healthcare associated infections and antimicrobial use in European acute care hospitals from the ECDC (European Centre for Disease Prevention and Control, 2012).

On average, just over one in ten people surveyed had at least one infection associated with medical care (HAI). Although the epidemiologic landscape of each country was unique, pneumonia and surgical site infections were the most prevalent among the surveyed countries.

An interesting point of the research was the fact that most of the surveyed participants, regardless of their HAI status, received antibiotics except the individuals managed in Brazil. The differential use of antimicrobials among the countries analyzed particularly stands out. Clearly, Mexico and Venezuela were the countries with the highest use of antimicrobials. The average use per capita in Mexico (1.31) and Venezuela (1.23) was the highest. Also, in these countries, 59.31% (Mexico) and 56.26% (Venezuela) of the patients analyzed were using at least one antimicrobial at the time of the study. In contrast, Brazil (0.44) exhibited the lowest per capita use, and with 29.43% of patients using at least one antimicrobial at the time of the study. On the other hand, Colombia showed a per capita use value of 0.95, but with 52.85% of the patients analyzed using at least one antimicrobial agent at the time of the study. Analyzing with the study's own data, the previous findings seem to be related to the level of registration of the indication for the use of antimicrobials in the notes of the medical records of the patients, since it is in Venezuela (29.2%) and in Mexico (39.1%), where the registry was ostensibly lower, when compared to Brazil, where registration was much higher (85.3%). This correlation seems to reflect low efficacy of antimicrobial administration policies in the hospitals of the countries analyzed,

Table 9
Risk Factors for HAIs by country.

Country	Total patients n	Average age (yrs)	<1 yr of age %	≥70 yrs of age %	Length of stay >7 days % (CI 95)	Surgery since admission % (CI 95)	McCabe score Ultimately and Rapidly fatal % (CI 95)	Invasive device use* % (CI 95)
Brazil	761	36.9	14.2%	25.0%	39.9% (36.5%-43.4%)	46.1% (42.6%-49.4%)	11.2% (8.9%-13.4%)	48% (41%-53%)
Colombia	386	41.0	11.4%	18.9%	49.2% (44.2%-54.2%)	40.9% (36.0%-45.9%)	33.4% (28.7%-38.1%)	65% (60%-71%)
Mexico	1,043	26.8	12.6%	11.9%	41.8% (38.8%-44.8%)	31.9% (29.0%-34.7%)	29.4% (26.6%-32.1%)	54% (51%-58%)
Venezuela	551	49.1	8.0%	12.7%	74.7% (71.1%-78.4%)	24.4% (20.7%-27-9%)	22.1% (18.7%-25.6%)	27% (23%-34%)

* CVC (central vein catheter), urinary catheter, intubation.

as well as lack of oversight, since all the hospitals participating in the study reported having a stewardship program. As to Global-PPS report, overall mean compliance to guidelines was 77·4%, but compliance was less than 70% in Latin America, west and central Asia, and Africa (Versporten et al., 2018). This is also a factor that may explain the high consumption of antibiotics in the region studied.

Carbapenems and third-generation cephalosporins were among the most commonly used antibiotics, although the high use of a wide variety of antimicrobial agents, including first-generation cephalosporins and penicillin combinations, including beta-lactamase inhibitors, stands out. We consider that our results add to WHO's recent efforts to understand antibiotic consumption in low and middle-income countries, of which we studied three that were not included on their report. We discuss our results in the light of previous evidence.

The prevalence of HAI among the four surveyed countries was 12%. In the United States of America, the prevalence of HAI is about 5%, representing significant departure from our results (WHO, 2016). However, our estimates are consistent with previous results in Latin American populations, where a prevalence of 10% had been reported (WHO, 2016). Our study is also consistent with a global survey of HAI that reported a prevalence of 11.9% (Versporten et al., 2018). Although our results for the general prevalence of HAI are also similar to what had been previously reported for Brazil (10.8%) (Fortaleza et al., 2017), we obtained a lower prevalence for this particular country (7.2%). This could be explained if we take into account that Brazil itself is region hard to summarize with the survey of 3 clinics. Another reason that could explain the difference is the type of facilities surveyed. Although we included a diverse set of hospitals, some particular services are at higher risk of HAI, including patients that receive chemotherapy. For instance, the prevalence of HAI among patients with cancer was of 73.6% in Brazil. Not considering this kind of outliers could make our results closer to the average, but may not take into account the whole picture of HAI in the specific surveyed facilities.

Pneumonia and bloodstream infections (laboratory confirmed) were the most frequent HAIs in Brazil. In Venezuela, the most frequent were pneumonia and infection related to vascular catheter (peripheral and central), while infections in the surgical site and pneumonia were the most frequent in Mexico and Colombia. Surgical specialties were more commonly surveyed in Mexico, giving explanation to our results from this country.

Previous studies conducted at general hospitals in Mexico City challenge our results since they report a higher prevalence of pneumonia (Aguilar-Rodea et al., 2015). However, pneumonia and soft tissue infections were the most common HAIs among Latin America countries in a recent survey (Versporten et al., 2018).

Four out of every five patients surveyed received an antibiotic, which was more pronounced in Mexico and Venezuela, where almost every patient received an antibiotic. Community-acquired infections were the most common reason to prescribe antibiotics, contrasting with previous results that reported HAI as the more important contributor to antibiotic use in Latin America (Versporten et al., 2018). Another point-prevalence study conducted in Latin American ICUs reported 40% of global antibiotic utilization, with pneumonia as the leading cause of prescription (Curcio and On behalf of the Latin American antibiotic use in intensive care unit group, 2011). Interestingly, we observed twice the prevalence of antibiotic utilization in our sample. The fact that the former study was conducted as three cross-sectional investigations may explain our different results. However, other studies estimated an antibiotic utilization in Latin America that approached 40% (Versporten et al., 2018). Also, noteworthy, antibiotic utilization has increased in Venezuela and Brazil, but not in Mexico and Colombia (Wirtz et al., 2010). However, that report considered the bulk sales of antibiotics without considering the specific setting of their administration.

Carbapenems and third-generation cephalosporins, were the most used antibiotics among the surveyed participants. Previous findings have raised concern about the widespread use of carbapenems and vancomycin in Latin America (Versporten et al., 2018). In line with those reports, we found that 16% of the individuals surveyed in Colombia, 12.8% of the Mexican and 12.2% of Venezuelan participants received carbapenems. Similarly, 15% of the participants in Venezuela received vancomycin. According to the 2018 WHO report on Surveillance of Antibiotic Consumption, penicillins accounted for more than 50% of Brazil's antibiotic consumption (WHO, 2019). Contrastingly, glycopeptide antibiotics and carbapenems were more frequently used in our sample. However, it is worth noticing that Brazil was the country with the highest usage of penicillins with extended spectrum and no *Pseudomonas* activity. While WHO used antibiotic consumption as a proxy for use, we measured use directly, which may account for the differences we found.

As we already mentioned, except from Brazil, nearly 55% of the antibiotics prescribed were not backed up with a justification in the medical record. Prior results demonstrated that this indicator could be as high as 81.4% in the region (Versporten et al., 2018). We believe that this seems to reflect low efficacy of antimicrobial administration policies in the hospitals of the countries analyzed, as well as lack of oversight and low Antibiotic Guidelines compliance.

Of the total cases of HAI, 42% presented positive microbiological results. The main group of microorganisms isolated was that of Enterobacteriaceae (41.4%), followed by gram-positive cocci (22%), and gram-negative bacilli non-Enterobacteriaceae (19.8%). We highlight that there were 10.6% of mycotic isolates (mostly Candida). In general, the specific microorganisms most frequently identified were Escherichia coli (6.6%), Klebsiella pneumoniae (6.4%), Staphylococcus aureus (4.7%), and Pseudomonas aeruginosa (3.5%).

The type of microorganisms isolated in HAIs in this research is very similar to that reported in a large study in Latin America (48,377 results of nosocomial cultures) in tertiary hospitals in 2016 (Arias-Flores et al., 2016), where Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, and Pseudomonas aeruginosa correspond to 4 of the 5 main isolates. This information corresponds to data 2015, while ours was collected in 2016.

These pathogens have been reported in the literature frequently and are members of the so-called ESKAPE group (Boucher et al., 2009).

The type of diagnosis (HAI, community acquired infections) and the groups of isolated microorganisms, as well as the specific microorganisms identified, explain, at least in part, the antimicrobial agents used in the different countries analyzed. Unfortunately, we could not obtain information on the resistance pattern of isolated microorganisms to antimicrobials.

Our results regarding the use of antibiotics in general in relation to the type of infection (community-acquired infections, HAIs), and the indication of prophylactic use, were similar when compared with the information from Latin America in the Global-PPS report (Versporten et al., 2018) which reflects data from 2015 vs ours that corresponds to 2016.

As to the risk factors for HAI registered and analyzed in this study, highlights ≥70 years of age within the study population of 25% in Brazil, the LOS > 7 days in Venezuela (74.7%), surgery during hospitalization in 46.1% in Brazil, McCabe's final score and fatal in Colombia and Mexico (nearly 30%), and use of invasive devices such as central vein catheter (CVC), urinary catheter and intubation, in Colombia (65% of the study population).

This study has some strengths, such as the sample studied (>2,700 patients, 11 tertiary hospitals, 4 Latin American countries), being the first multicenter-multinational study of this type in the Latin American region reported, and also, incorporating into the analysis of the OD Point Prevalence of HAIs, a detailed analysis of the pattern of antimicrobial use in the hospital. Additionally, we incorporated a diverse population that included ICU, psychiatric, internal medicine and pediatric participants. Moreover, we investigated public hospitals attending different populations at distinct locations in Latin America. Furthermore, our sample size enables us to draw conclusions that could be applied out of our population. Nevertheless, our results face some limitations, for instance, we only took a snapshot of the regional prevalence of HAI, although we gathered microbiological information from 42% of HAIs; unfortunately, we could not obtain information on the resistance pattern of isolated microorganisms to antimicrobials. Also, although it was sought to individualize the data of pediatric HAIs as much as possible in the tables, no information was available in such a way as to allow reporting this data separately from that of the adults. It is relevant to mention that pediatric cases corresponded to 18.4% for <10 years of age, and to 11.9% for <12 months of age. It is also relevant to bear in mind that the data was collected in 2016 and may not reflect current use or resistance issues. Therefore, extrapolating these results to different periods of time could be misleading. Future studies are on their way to investigate one-day prevalence of HAI at different calendar times, allowing us to inquire temporal patterns.

We aimed to conduct a cross-sectional study to understand the direct impact and burden of HAI in Latin American countries where data is not available. We believe that our results will help to prioritize areas of research in the region in order to conduct target surveillance of HAI incidence, and to understand more in depth the differential use of antimicrobials in the region.

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Specific author contributions

Huerta-Gutiérrez R: Study design and conceptualization, drafting the manuscript, participating extensively in the manuscript critical review. Has approved the final draft.

Rosado-Buzzo A: Study design and conceptualization, drafting the manuscript, participating extensively in the manuscript critical review. Has approved the final draft.

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Conflicts of interest

All authors declare that they have no conflict of interest.

Ethical approval has been granted by all the ethics committees in the participating hospitals.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2019.06.016.

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