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Prevalence of Bacterial Resistance from 2016 to 2018 at the General Hospital of Obregon, Sonora

Prevalencia de resistencia bacteriana de 2016 a 2018 en el Hospital General de Obregón, Sonora

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ABSTRACT

Antimicrobial resistance in Mexico is difficult to address due to the absence of a regulatory instance that effectively control the use and sale of antimicrobials; and the low surveillance of prescription and self-medication. This study aimed to determine the prevalence of bacterial resistance to antibiotics isolated from clinical samples in the General Hospital of Obregon, Sonora. Information was obtained from the culture logs processed and analyzed at the Microbiology area of the Clinical Laboratory and its resistance to antibiotics, from December 2016 to January 2018. *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus* infections were the most common among patients from all care services. Bacteria such as *S. aureus* and *E. coli*, showed antibiotic resistance of up to 90 and 100 %. A high resistance was observed against benzylpenicillin at the intensive care unit service (100 %). High bacterial resistance to antibiotics was found from December 2016 to January 2018 in the present study, and this apparently remains unchanged in our country which was inferred by data reported by previous few Mexican studies.
Keywords: Antimicrobial resistance; Surveillance; Antibiotics; Antibiogram; *E. coli*; Mexican hospital.

RESUMEN

En México, la resistencia a los antimicrobianos es difícil de abordar debido a la ausencia de un organismo regulador que controle de manera efectiva el uso y la venta de antimicrobianos; y la baja vigilancia de prescripción y automedicación. Este estudio tuvo como objetivo determinar la prevalencia de resistencia a antibióticos en bacterias aisladas de muestras clínicas en el Hospital General de Obregón, Sonora. En este estudio se recolectó información de los cultivos que se realizaron en el área de Microbiología del Laboratorio de Análisis Clínicos y su resistencia a antibióticos, desde diciembre de 2016 hasta enero de 2018, en el Hospital General de Obregón, Sonora. Las infecciones por *Escherichia coli*, *Klebsiella pneumoniae* y *Staphylococcus aureus* fueron las más frecuentes entre los pacientes de todos los servicios de atención. Bacterias, como *E. coli* y *S. aureus* mostraron resistencia a los antibióticos hasta en un 90 y 100 %. La bencilpenicilina fue el antibiótico al que se observó alta resistencia en el servicio de cuidados intensivos (100 %). En el presente estudio se encontró una alta resistencia bacteriana a los antibióticos desde diciembre de 2016 hasta enero de 2018 y, en comparación con pocos estudios mexicanos, se ha mantenido sin cambios.
Palabras clave: Resistencia antimicrobiana; Vigilancia; Antibióticos; Antibiograma; *E. coli*; hospital mexicano.

INTRODUCTION

Antimicrobial resistance occurs when microorganisms, such as bacteria, acquire or develop biological mechanisms that make drugs no longer effective. This phenomenon can cause different problems in health systems, ranging from high morbidity and mortality to high medical costs worldwide (Kok *et al*., 2022; Liguori *et al*., 2022).

In Mexico, the concern of optimal surveillance in hospitals on bacterial resistance or multi-resistance has grown recently. The main bacteria associated with infections reported by Mexican hospitals include *Escherichia coli*, *Salmonella* spp., *Enterococcus* spp., *Staphylococcus aureus*, *Klebsiella* spp., *Shigella* spp. and *Acinetobacter baumannii* (Garza-González *et al*., 2020).

Some factors can lead to the presence of these infections, for example the reduction of patient immunity, a greater variety of medical procedures, invasive techniques, and the transmission of drug-resistant bacteria within patients in crowded hospitals (Bakkeren *et al*., 2020). On the other hand, factors such as age, sex, nutritional status, and the presence of other concomitant pathologies can also play an important role (Humphries *et al*., 2021). Even so, there are different variations and frequencies of these infections among populations which should be recorded for a better understanding of the problem, and to propose specific solutions.

Despite some epidemiological surveillance programs in northwest Mexico, a high rate of resistance to first-choice antibiotics is reported by health institutions (Bolado-Martínez

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et al., 2018; 2022). A systematic governance analysis of global response to antimicrobial resistance, revealed a lack of research, monitoring, and evaluation of this health problem in Mexico. This is a reason for alert which encourages greater care in resistance patterns and surveillance programs (Patel *et al*., 2023). This step is important to know the length of the problem at the different health centers in northwest Mexico (Navarro-Navarro *et al*., 2013), to supports decision-makers to build programs with actions to reduce the prevalence, morbidity and mortality associated to bacterial antibiotic resistance.

Therefore, the present work aims to generate two-year-epidemiological information on the prevalence of antibacterial resistance from samples of different service areas in a second Level Hospital in Northwest Mexico.

MATERIAL AND METHODS

A retrospective study was carried out at a hospital of northwest Mexico. Information was collected from the culture logs of processed and analyzed samples at the Microbiology area of the Clinical Laboratory, from December 2016 to January 2018. Data from 1915 cultures with and without antibiogram from hospitalized and non-hospitalized patients (External Consultation area) were collected and processed using an Excel program database. Complete antibiogram and complete demographic information (date of the study, sex, age, and hospital unit service) was considered as inclusion criteria (n = 834). The age-range was from 0 to 99 years old. The diagnostic equipment used was the VITEK® 2 Compact (Biomeireux) with an extensive database for the identification of different microorganisms, which included information on bacterial sensitivity (S) and resistance (R) to different antibiotics. The collected data underwent processing, enabling analysis of the prevalence by bacterial species and care services.

Statistical Analysis

The prevalence of isolated bacteria was estimated by age groups, sex, and service areas. In addition, these variables were used to determine the prevalence of bacterial resistance and sensitivity. The above was calculated as percentage using the formula: P = (PR/N) x 100, where PR is the number of samples with bacterial resistance and/or sensitivity to antibiotics, N is the total number of samples recorded, and multiplied by one hundred. Difference between Gram-positive and Gram-negative bacteria, and the prevalence of antibiotic resistance and/or sensitivity was compared using the two sided Chi-square test with the package SPSS, 2011, at significant level of $p < 0.05$.

RESULTS AND DISCUSSION

General prevalence.

An overall bacterial prevalence of 42.8 % from 1945 records within the period December 2016 and January 2018 was estimated. The prevalence of bacterial species is shown in Table 1. *Escherichia coli* (44.3 %) showed the highest prevalence followed by *Klebsiella pneumoniae* (7.2 %), *Staphylococcus aureus* (6.3 %), *Staphylococcus epidermidis* (6.2 %) and *Pseudomonas aeruginosa* (5.2 %). On the other hand, *Staphylococcus capitis*, *Staphylococcus lugdunensis*, *Achromobacter denitrificans*, *Aeromonas caviae*, *Cronobacter sakazakii*, *Raoultella ornithinolytica*, *Sphingomonas paucimobilis*, *Morganella* spp., *Shigella sonnei*, *Achromobacter xylosoxidans*, *Plesiomonas shigelloides*, *Ralstonia pickettii*, *Streptococcus intermedius*, *Enterococcus faecium*, *Bacillus* spp., *Kocuria rosea*, *Streptococcus dysgalactiae*, *Streptococcus parasanguinis* and *Streptococcus constellatus* showed the lowest prevalence (≈ 0.12 %).

Regarding the high prevalence of *E. coli*, *K. pneumoniae*, *S. aureus*, *S. epidermidis* and *P. aeruginosa* found in this study, a number of studies in the European Union (19,888 patients) published in 2012 also reported a high prevalence of hospital infections by *E. coli* (15.2 %), *S. aureus* (12.1 %), *P. aeruginosa* (11.2 %), and *K. pneumoniae* (8.1 %) (Zarb *et al*., 2012). Despite the level of prevalence and rank order are different to our results, the isolated bacterial species are the same. On the other hand, a surveillance network (PRONARES) in Chile, reported *E. coli* (35.9 %), *S. aureus* (20.6 %), and *Klebsiella* spp. (9.5%) as the predominant isolated species from a total of 5,251 biological samples (Trucco *et al*., 2002). Similarly, a meta-analysis from 40 different studies published in 2022, reported diarrheagenic *E. coli* as the most prevalent bacteria in Asia (22.8%) (Salleh *et al*., 2022). However, identification of type of *E. coli* in this study was not performed.

Prevalence according to Gram classification

Regarding 834 Gram stains, the prevalence of Gram-negative bacteria was significantly higher (613 isolates; 73.5 %) than Gram-positive bacteria (221 isolates; 26.5 %) ($p < 0.05$) (Figure 1).

In Mexico, reports from Leon Guanajuato and Mexico city in 2012 revealed a higher prevalence of Gram-positive (51.2 %) than Gram-negative bacteria (48.8 %) from 5,117 clinical cultures (Duarte-Raya and Granados-Ramírez, 2012). On the other hand, a previous study carried out at the State Cancer Center of ISSEMYM (Social Security Institute of the State of Mexico and Municipalities) in Mexico, reported 787 (59.9 %) infections associated to Gram-negative bacteria and 401 (30.5 %) to Gram-positive bacteria from a total of 1,313 infections (Romero *et al*., 2013). Differences between these trends may be attributed to influx of staff, patients, and contact with outside air in waiting rooms, and different cleaning and disinfection procedures by hospital services (Zambrano-Gari and Luna-Fontalvo, 2013).

Prevalence of bacteria per service unit

Table 2 shows the bacterial prevalence from 834 positive records per service unit. The service with the highest overall prevalence of bacterial species was the internal medicine (IM) with 241 isolates (28.8 %), followed by external consultation (EC) with 133 isolates (15.9 %); gynecology (GYNE) with 82 isolates (9.8 %); neonatal special care unit (NSCU) with 81

Table 1. General prevalence of bacterial species isolated from clinical samples (n = 834).
Tabla 1. Prevalencia general de especies bacterianas aisladas de muestras clínicas (n = 834).

Bacterial specie	Prevalence n (%)	Bacterial specie	Prevalence n (%)
Escherichia coli	371 (44.3 %)	*Acinetobacter iwoffii*	2 (0.2 %)
Klebsiella pneumoniae	61 (7.2 %)	*Pantoea spp.*	2 (0.2 %)
Staphylococcus aureus	53 (6.3 %)	*Streptococcus anginosus*	2 (0.2 %)
Staphylococcus epidermidis	52 (6.2 %)	*Streptococcus gallolyticus*	2 (0.2 %)
Pseudomonas aeruginosa	44 (5.2 %)	*Staphylococcus capitis*	1 (0.1 %)
Enterobacter cloacae	41 (4.9 %)	*Staphylococcus lugdunensis*	1 (0.1%)
Staphylococcus haemolyticus	34 (4.0 %)	*Achromobacter denitrificans*	1 (0.1 %)
Acinetobacter baumannii	26 (3.1 %)	*Aeromonas caviae*	1 (0.1 %)
Enterococcus faecalis	16 (1.9 %)	*Cronobacter sakazakii*	1 (0.1 %)
Proteus mirabilis	16 (1.9 %)	*Raoultella ornithinolytica*	1 (0.1 %)
Staphylococcus hominis	15 (1.7 %)	*Sphingomonas paucimobilis*	1 (0.1 %)
Streptococcus mitis	15 (1.7 %)	*Morganella spp.*	1 (0.1 %)
Staphylococcus warneri	11 (1.3 %)	*Shigella sonnei*	1 (0.1 %)
Enterobacter aerogenes	9 (1.0 %)	*Achromobacter xylosoxidans*	1 (0.1 %)
Morganella morganii	7 (0.8 %)	*Plesiomonas shigelloides*	1 (0.1%)
Citrobacter freundii	5 (0.6 %)	*Ralstonia pickettii*	1 (0.1 %)
Shigella spp.	5 (0.6 %)	*Streptococcus intermedius*	1 (0.1 %)
Serratia marcescens	4 (0.4 %)	*Enterococcus faecium*	1 (0.1 %)
Klebsiella oxytoca	4 (0.4 %)	*Bacillus spp.*	1 (0.1 %)
Streptococcus pneumoniae	4 (0.4 %)	*Kocuria rosea*	1 (0.1 %)
Streptococcus pyogenes	4 (0.4 %)	*Streptococcus dysgalactiae*	1 (0.1 %)
Stenotrophomonas maltophilia	4 (0.4 %)	*Streptococcus parasanguinis*	1 (0.1 %)
Streptococcus agalactiae	3 (0.3 %)		
Pseudomonas putida	2 (0.2 %)	*Streptococcus constellatus*	1 (0.1 %)
Providencia rettgeri	2 (0.2 %)		

n =number of bacterial isolates.

isolates (9.7 %); pediatrics (PED) and emergency department (ED) with 75 isolates each one (8.9 %); surgery (SUR) with 64 (7.6 %); and pediatric emergencies (PEDE) with 52 (6.2 %). The intensive care unit (ICU) service showed the lowest prevalence (15 isolates, 1.7 %).

The area with the highest reported infections was the IM (28.8 %) in this study. A study carried out in 2013 with 126 patients at the Mexican Social Security Institute in Salamanca, Guanajuato, and Mexico City, reported a 9.5 % prevalence of hospital infections from which the highest prevalence (16.2 %) was observed at the IM area, followed by the SUR (12.5 %), the traumatology and orthopedics (5 %), and the GYNE and obstetrics (3.1 %). The high prevalence of infections at the IM in this study, is probably associated to the location of the urology service at the IM, where most urine culture analysis are performed (Castañeda-Martínez and Valdespino-Padilla, 2015).

In relation to EC, the second service unit with the major number of isolates, it showed the highest demand for

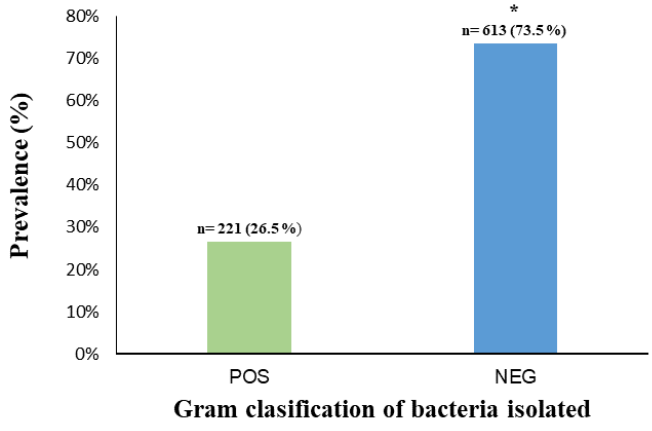

Figure 1. General prevalence (%) of bacterial isolates from 834 clinical samples according to their Gram classification. *Significant p-value by the Chi-square test.
Figura 1. La prevalencia general (%) de bacterias aisladas de 834 aislamientos de muestras clínicas según su clasificación Gram. *Valor p significativo por Chi-cuadrado prueba.

Table 2. Prevalence of bacterial species isolated from clinical samples (n=834) by care services.
Tabla 2. Prevalencia de especies bacterias aisladas de muestras clínicas (n=834) por servicios asistenciales.

Bacteria specie	EC	SUR	GYNE	IM	PED	ICU	NSCU	ED	PEDE	INTERN
S. aureus	10.5%	4.6%	3.6%	3.3%	17.3%	6.6%	4.9%	5.3%	5.7%	0.0%
S. haemolyticus	3.7%	4.6%	3.6%	1.6%	6.6%	20.0%	7.4%	4.0%	3.8%	0.0%
S. hominis	3.0%	0.0%	1.2%	0.4%	2.6%	13.3%	3.7%	2.6%	0.0%	0.0%
S. warneri	6.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.2%
S. epidermidis	3.7%	3.1%	1.2%	1.2%	10.6%	6.6%	34.5%	1.3%	0.0%	18.7%
S. agalactiae	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
S. capitis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
S. lugdunensis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
E. faecalis	3.0%	3.1%	0.0%	2.0%	0.0%	6.6%	2.4%	2.6%	1.9%	0.0%
S. agalactiae	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
S. intermedius	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
S. mitis	0.7%	3.1%	0.0%	3.3%	2.6%	0.0%	0.0%	2.6%	0.0%	0.0%
S. anginosus	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
S. pneumoniae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	1.9%	6.2%
S. gallolytticus	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
S. pyogenes	0.7%	0.0%	0.0%	0.4%	1.3%	0.0%	0.0%	0.0%	1.9%	0.0%
Bacillus spp.	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
K. rosea	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
S. dysgalactiae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
S. parasanguinis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
S. constellatus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
E. coli	48.8%	43.7%	65.8%	58.0%	22.6%	6.6%	22.%	30.6%	34.6%	37.5%
K. pneumoniae	7.5%	7.8%	9.7%	7.4%	12.0%	0.0%	3.7%	8.0%	3.8%	0.0%
K. oxytoca	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	2.6%	1.9%	0.0%
A. baumannii	0.7%	6.2%	0.0%	3.3%	2.6%	13.%	1.2%	5.3%	1.9%	18.7%
A. iwoffii	0.0%	0.0%	0.0%	0.4%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%
S. maltophilia	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pantoea spp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	6.2%
S. marcescens	0.0%	1.5%	0.0%	0.4%	0.0%	0.0%	1.2%	0.0%	1.9%	0.0%
Shigella spp.	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	2.6%	3.8%	0.0%
S. sonnei	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
E. aerogenes	0.0%	0.0%	1.2%	0.0%	1.3%	13.%	3.7%	2.6%	1.9%	0.0%
E. cloacae	5.2%	6.2%	2.4%	3.3%	10.6%	0.0%	8.6%	0.0%	3.8%	6.2%
Morganella spp.	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
M. morganii	0.0%	3.1%	0.0%	1.2%	0.0%	0.0%	0.0%	1.3%	1.9%	0.0%
A. denitrificans	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%
A. xylosoxidans	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%
P. aeruginosa	2.2%	7.8%	0.00%	7.8%	4.0%	13.%	6.1%	4.0%	7.6%	0.0%
P. putida	0.0%	0.0%	1.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
P. mirabilis	0.0%	3.1%	0.0%	1.2%	1.3%	0.0%	0.0%	4.0%	3.8%	0.0%
A. caviae	0.0%	0.0%	6.1%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%
C. sakazakii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
C. freundii	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	2.6%	1.92%	0.0%
R. ornithinolytica	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
TOTAL (n%)	133 15.9%	64 7.6%	82 9.8%	241 28.8%	75 8.9%	15 1.7%	81 9.7%	75 8.9%	52 6.2%	16 1.9%

n = number of bacterial isolates per care services; External Consultation (EC); Surgery (SUR); Gynecology (GYNE); Internal Medicine (IM); Pediatrics (PED); Gynecology (GYNE), Internal Medicine (IM); Intensive Care Unit (ICU); Neonatal Special Care Unit (NSCU); Emergency Department (ED); Pediatric Emergencies (PEDE).

laboratory requests. Therefore, this area can be regarded as an indicator of frequency and type of bacterial infections affecting a community.

On the other hand, a 2014 study of 360 samples at the Fernando Troconis University Hospital in Colombia, reported *S. haemolyticus* as the most prevalent bacterium at the ICU service (81.1 %) (Vélez-Pereira and Caicedo, 2014). In this study, this bacterium also showed the highest prevalence at the ICU service (20 %). It should be noted that this bacterium can be easily transmitted between the potential sources of infection and hosts, such as patients, medical personal, and routine equipment.

Apparently, the uncontrolled application of broad-spectrum antibiotics in ICU patients promotes the settlement of bacterial infections by opportunistic pathogens. This may be due to unawareness of the site of infection and the etiological agent, or prolonged use of catheters and often probes, as well as the contamination provoked by the personnel in charge of patient care (Russotto *et al*., 2015).

Prevalence by age and sex groups

Table 3 shows the prevalence of the main bacterial species isolated by age groups from 834 isolates. *E. coli* was predominant in all age groups, and increased with age, being those over 60 years (52 %) the most susceptible age group. A study carried out at two cities of Honduras in 2014, analyzed 602 bacterial isolates, of which 84 (14 %) were from the 0-10 years group, 30 (5 %) from the 11 - 20 years group, 260 (43 %) from the 21 - 60 years group, and 205 (34 %) from people over 61 years old. In addition, authors observed a higher prevalence of hospital infections in people over 18 years of age, but particularly in the age over 60 years (Zúniga-Moya *et al*., 2016). It was proposed that older people are more sensitive to various stressors associated to a progressive loss of cellular homeostasis which may lead to immunosenescence and greater exposure to different ailments (Ciaglia *et al*., 2022).

Table 3. Prevalence of bacteria isolated from 834 clinical samples by age groups.
Tabla 3. Prevalencia de bacterias aisladas de 834 muestras clínicas por grupos de edad.

Age (N)	Bacteria specie	n (%)
0-17 (268)	*E. coli*	79 (29.4 %)
	S. epidermidis	40 (14.9 %)
	S. aureus	29 (10.8 %)
	E. cloacae	24 (8.9 %)
18-59 (413)	*E. coli*	210 (50.8 %)
	K. pneumoniae	37 (8.9 %)
	S. aureus	20 (4.8 %)
	P. aeruginosa	16 (3.8 %)
60-99 (153)	*E. coli*	81 (52.9 %)
	P. aeruginosa	16 (10.4 %)
	K. pneumoniae	11 (7.1 %)
	E. faecalis	5 (3.2 %)

N= total number per age of bacterial isolates of patients; n= number of bacterial isolates.

On the other hand, Table 4 shows *E. coli* as the most isolated bacteria from male and female patients. A higher prevalence was observed in female (50.8 %), with 251 isolates, than in male (35 %) patients with 119 isolates ($p < 0.05$). Furthermore, male had a higher prevalence of infections by *P. aeruginosa* (9.4 %), *S. aureus* (8.2 %) and *E. cloacae* (7.3 %).

The disparity in infection prevalence between male and female patients may be explained by the anatomical and physiological differences which may promote a greater predisposition to urinary tract infections, particularly in female (Alós, 2005). Likewise, other studies have reported that female are more susceptible to infections, but a clear physiological explanation for this event has not yet been proposed (Combes *et al*., 2009).

Table 4. Prevalence of the main bacteria isolated from 494 female and 340 male clinical samples.
Tabla 4. Prevalencia de las principales bacterias aisladas de muestras clínicas de 494 mujeres y 340 hombres.

Bacteria isolated	Female n (%)	Male n (%)	p
E. coli	251 (50.8 %)	119 (35 %)	< 0.05*
K. pneumoniae	37 (7.5 %)	24 (7.1 %)	> 0.05
S. epidermidis	33 (6.7 %)	19 (5.6 %)	> 0.05
S. aureus	25 (5.1 %)	28 (8.2 %)	> 0.05
S. haemolyticus	21 (4.3 %)	13 (3.8 %)	> 0.05
E. cloacae	16 (3.2 %)	25 (7.4 %)	< 0.05*
P. aeruginosa	12 (2.4 %)	32 (9.4 %)	< 0.05*
P. mirabilis	12 (2.4 %)	-	-
S. warneri	10 (2.0 %)	-	-
A. baumannii	9 (1.8 %)	17 (5 %)	< 0.05*

*Significant p value by the Chi-square test. - No report of cases.

Prevalence of resistance and sensitivity

Table 5 shows the resistance and sensitivity prevalence by the most isolated bacteria from 834 clinical samples. The highest resistance was shown by *K. pneumoniae* to ampicillin (AMP) (100 %) and nitrofurantoin (NIT) (50.0 %); *P. aeruginosa* to trimethoprim/sulfamethoxazole (SXT) (100.0 %), AMP (97.6 %), and ampicillin/sulbactam (SAM) (97.6 %); *Enterobacter cloacae* to cefazolin (CZO) (100 %) and NIT (69.4 %), *S. aureus* (90.3 %) and *S. epidermidis* (97.7 %) to benzylpenicillin (PEN); and *E. coli* to AMP (78.3 %) and SAM (68.4 %).

On the other hand, the species which showed the highest sensitivity were *E. coli* to meropenem (MEM) (99.4 %) and tigecycline (TGC) (99.1 %); *K. pneumoniae* (98.2 %) to MEM, ertapenem (ETP), and amikacin (AMK); *S. aureus* (98.0 %) to TGC, vancomycin (VAN), SXT, NIT, Quinupristin/Dalfopristin (QDA), Linezolid (LNZ), and Rifampicin; *S. epidermidis* (100 %) to TGC, QDA, NIT, and LNZ; *P. aeruginosa* (72.09 %)to gentamicin (GEN) and Piperacillin/Tazobactam (TZP); and *E. cloacae* (88.89 %)to MEM, AMK, and TGC.

Table 5. Prevalence of bacterial resistance (%R) and sensitivity (%S) to the most frequently used antibiotics.
Tabla 5. Prevalencia de resistencia bacteriana (%R) y sensibilidad (%S) a los antibióticos más utilizados

Antibiotic	*E. coli*		*K. pneumoniae*		*S. aureus*		*S. epidermidis*		*P. aeruginosa*		*E. cloacae*	
	%R	%S	%R	%S	%R	%S	%R	%S	%R	%S	%R	%S
AMP	78.3%	21.4%	100.0%	0.0%	-	-	-	-	97.6%	2.3%	-	-
PEN	-	-	-	-	90.3%	9.6%	97.7%	2.2%	-	-	-	-
OXA	-	-	-	-	11.5%	88.4%	86.3%	13.6%	-	-	-	-
CZO	40.0%	60.0%	20.6%	79.3%	-	-	-	-	100.0%	0.0%	100.0%	0.0%
CRO	38.0%	61.9%	20.6%	79.3%	-	-	-	-	97.6%	2.3%	47.2%	52.7%
FEP	37.1%	62.8%	20.6%	79.3%	-	-	-	-	34.8%	65.1%	16.6%	83.3%
ATM	37.1%	62.8%	20.6%	79.3%	-	-	-	-	-	-	47.2%	52.7%
SAM	68.4%	31.5%	34.4%	65.5%	-	-	-	-	97.6%	2.3%	-	-
TZP	11.2%	87.6%	15.5%	84.4%	-	-	-	-	23.2%	72.0%	25.0%	75.0%
ETP	0.5%	99.1%	1.7%	98.2%	-	-	-	-	50.0%	50.0%	16.6%	83.3%
MEM	0.2%	99.4%	1.7%	98.2%	-	-	-	-	34.8%	65.1%	11.1%	88.8%
CIP	47.6%	52.3%	24.1%	75.8%	11.5%	88.4%	65.9%	34.0%	34.8%	65.1%	13.8%	86.1%
LVX	-	-	-	-	11.5%	88.4%	65.9%	34.0%	-	-	-	-
MFX	-	-	-	-	9.6%	90.3%	38.6%	61.3%	-	-	-	-
AMK	1.1%	98.8%	1.7%	98.2%	-	-	-	-	34.8%	65.1%	11.1%	88.8%
GEN	29.8%	70.1%	12.0%	87.9%	3.8%	96.1%	77.2%	22.7%	27.9%	72.0%	16.6%	83.3%
TOB	34.9%	65.0%	24.1%	75.8%	-	-	-	-	34.8%	65.1%	30.5%	69.4%
NIT	12.6%	87.3%	50.0%	50.0%	1.9%	98.0%	0.0%	100.0%	100.0%	0.0%	69.4%	30.5%
SXT	56.9%	42.5%	29.3%	70.6%	1.9%	98.0%	61.3%	38.6%	100.0%	0.0%	33.3%	66.6%
ERY	-	-	-	-	13.4%	86.5%	79.5%	20.4%	-	-	-	-
CLI	-	-	-	-	13.4%	86.5%	65.9%	34.0%	-	-	-	-
TCY	-	-	-	-	3.8%	96.1%	6.8%	93.1%	-	-	-	-
TGC	0.5%	99.1%	5.1%	94.8%	1.9%	98.0%	0.0%	100.0%	100.0%	0.0%	11.1%	88.8%
QDA	-	-	-	-	1.9%	98.0%	0.0%	100.0%		-	-	-
LNZ	-	-	-	-	1.9%	98.0%	0.0%	100.0%	-	-	-	-
RIF	-	-	-	-	1.9%	98.0%	2.2%	97.7%	-	-	-	-
VAN	-	-	-	-	1.9%	98.0%	2.2%	97.7%	-	-	-	-
ESBL	38.3%	61.6%	20.6%	79.3%								

Ampicillin (AMP); Benzylpenicillin (PEN); Oxacillin (OXA); Cefazolin (CZO); Ceftriaxone (CRO); Cefepime (FEP); Aztreonam (ATM); Ampicillin/Sulbactam (SAM); Piperacillin/Tazobactam (TZP); Ertapenem (ETP); Meropenem (MEM); Ciprofloxacin (CIP); Levofloxacin (LVX); Moxifloxacin (MFX); Amikacin (AMK); Gentamicin (GEN); Tobramycin (TOB); Nitrofurantoin (NIT); trimethoprim/sulfamethoxazole (SXT); erythromycin (ERY); Clindamycin (CLI); Tetracycline (TCY); Tigecycline (TGC); Quinupristin/Dalfopristin (QDA); Linezolid (LNZ); Rifampicin (RIF); Vancomycin (VAN); extended spectrum beta-lactamases (ESBL).

Among the few published Mexican studies on bacterial resistance, the State Oncology Center of the Mexican Institute of Social Security of the State of Mexico, and Municipalities (ISSEMYM) in 2012, analyzed 4,652 samples and reported a high resistance of *E. coli* to AMP (86.7 %), ciprofloxacin (86.1 %), levofloxacin (85.3 %); and from 1,313 records *P. aeruginosa* (100 %) to tetracycline, CZO, and ceftriaxone (CRO). In addition, *S. aureus*, showed a high resistance to PEN (92.2 %), erythromycin (62.9 %), and clindamycin (62.4 %), and *S. epidermidis* with a similar resistance trend to the same antibiotics (Romero *et al*., 2013). On the other hand, it has been recognized that the most common resistant bacteria associated to hospital infections are *E. coli*, *K. pneumoniae*, and *P. aeruginosa* (Rello *et al*., 2019). In addition, an increase in resistance has been observed against CRO and amoxicillin (Rolain *et al*., 2016). It is probably that the number of bacteria capable of generating extended-spectrum beta-lactamases (ESBL) has increased worldwide (Hermann *et al*., 2006).

Antimicrobial resistance mechanisms can be categorized into four primary groups: (1) restricting drug uptake, (2) altering drug targets, (3) deactivating drugs, and (4) actively expelling drugs. Intrinsic resistance may involve limited drug uptake, drug deactivation, and drug efflux; while acquired resistance mechanisms may include modifying drug targets, drug deactivation, and drug efflux. Variations in structures lead to differences in the mechanisms used by gram-negative

and gram-positive bacteria. Gram-negative bacteria use all four main mechanisms, while gram-positive bacteria use less frequently the limiting drug uptake (due to the absence of an LPS outer membrane) and lack the capacity for certain types of drug efflux mechanisms (Reygaert, 2018).

Finally, a high prevalence of *A. baumanni* (8.61 %), *E. coli* (38.03 %), *K. pneumoniae* (37.41 %) and *P. aeruginosa* (15.94%) have been reported by some hospitals in Saudi Arabia (Aloraifi *et al*., 2023). A systematic review, from 2011 to 2021, reported that these bacteria are the most common multridrug-resistant specifically to aztreonam, ceftazidime, cefotaxime, related cxyimino-β-lactams, cephalosporins, and penicillins (Borgio *et al*., 2021; Pishtiwan and Khadija, 2019). Apparently, the trends of bacterial resistance based on previous few published Mexican study data and those from this study remains unchanged, and probably is expected that this health problem increases in Mexico.

CONCLUSIONS

This study revealed a high prevalence of bacterial resistance to the first-choice antibiotics at a hospital of northwest Mexico. Infections caused by Gram-negative were more prevalent (73.5 %) than Gram-positive bacteria (26.5 %). In addition, *E. coli*, *K. pneumoniae* and S. *aureus* were the most isolated bacteria species in all care services of the study hospital. *E. cloacae*, *P. aeruginosa*, and *A. baumannii*, showed a higher prevalence in male than in female, but it was the opposite trend for infections by *E. coli*. Also, a high resistance of *E. coli* to AMP (78.3 %), SAM (68.4 %), SXT (56.9 %) and ESBL (36.6 %) was found. Based on this, effective actions to reduce the impact caused by the inappropriate use of antibiotics at both local and national levels must be taken.

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CONFLICTS OF INTEREST

All authors have no conflict of interest to declare.

REFERENCES

Aloraifi, R.I., Alharthi, A.F., Almefleh, A.A., Alamri, A.H., Alobud, A.S., Bawazeer, R.A., Alswaji, A.A., Alalwan, B., Aldriwesh, M.G., Johani, S.M.A., and 2023. Prevalence of Carbapenem Non-susceptible Gram-Negative Bacteria at Tertiary Care Hospitals in Saudi Arabia. Cureus 15. https://doi.org/10.7759/cureus.33767

Alós, J.I. 2005. Epidemiología y etiología de la infección urinaria comunitaria. Sensibilidad antimicrobiana de los principales patógenos y significado clínico de la resistencia. Enfermedades Infecciosas y Microbiología Clínica 23, 3–8.

Bakkeren, E., Diard, M. and Hardt, W. D. 2020. Evolutionary causes and consequences of bacterial antibiotic persistence. Nature Reviews Microbiology 18, 479–490.

Bolado-Martínez, E., Nevárez-López, A.R. and Candia-Plata, M. del C. 2018. Vigilancia de la resistencia bacteriana en instituciones de salud de la ciudad de Hermosillo, Sonora, México. Salud Pública de México 60, 117–119. https://doi.org/10.21149/8560

Borgio, J.F., Rasdan, A.S., Sonbol, B., Alhamid, G., Almandil, N.B. and AbdulAzeez, S. 2021. Emerging Status of Multidrug-Resistant Bacteria and Fungi in the Arabian Peninsula. Biology (Basel) 10, 1144. https://doi.org/10.3390/biology10111144

Castañeda-Martínez, F.C. and Valdespino-Padilla, M.G. 2015. Prevalencia de infecciones nosocomiales en un hospital de segundo nivel de atención en México. Revista Médica del Instituto Mexicano del Seguro Social 53, 686–690.

Ciaglia, E., Lopardo, V., Montella, F., Carrizzo, A., Di Pietro, P., Malavolta, M., Giacconi, R., Orlando, F., Cattaneo, M., Madeddu, P., Vecchione, C. and Puca, A.A. 2022. Transfer of the longevity-associated variant of BPIFB4 gene rejuvenates immune system and vasculature by a reduction of CD38+ macrophages and NAD+ decline. Cell Death & Disease 13, 1–10. https://doi.org/10.1038/s41419-022-04535-z

Combes, A., Luyt, C.-E., Trouillet, J.-L., Nieszkowska, A. and Chastre, J. 2009. Gender impact on the outcomes of critically ill patients with nosocomial infections. Critical Care Medicine 37, 2506–2511. https://doi.org/10.1097/CCM.0b013e3181a569df

Duarte-Raya, F. and Granados-Ramírez, M.P. 2012. Resistencia antimicrobiana de bacterias en un hospital de tercer nivel. Revista Médica del Instituto Mexicano del Seguro Social 50, 289–300.

Garza-González, E., Franco-Cendejas, R., Morfín-Otero, R., Echaniz-Aviles, G., Rojas-Larios, F., Bocanegra-Ibarias, P., Flores-Treviño, S., Ponce-de-León, A., Rodríguez-Noriega, E., Alavez-Ramírez, N., Mena-Ramirez, J.P., Rincón-Zuno, J., Fong-Camargo, M.G., Morales-De-la-Peña, C.T., Huerta-Baltazar, C.R., López-Jacome, L.E., Carnalla-Barajas, M.N., Soto-Noguerón, A., Sanchez-Francia, D., Moncada-Barrón, D., Ortíz-Brizuela, E., García-Mendoza, L., Newton-Sánchez, O.A., Choy-Chang, E.V., Aviles-Benitez, L.K., Martínez-Miranda, R., Feliciano-Guzmán, J.M., Peña-Lopez, C.D., Couoh-May, C.A., López-Gutiérrez, E., Gil-Veloz, M., Armenta-Rodríguez, L.C., Manriquez-Reyes, M., Gutierrez-Brito, M., López-Ovilla, I., Adame-Álvarez, C., Barajas-Magallón, J.M., Aguirre-Burciaga, E., Coronado-Ramírez, A.M., Rosales-García, A.A., Sida-Rodríguez, S., Urbina-Rodríguez, R.E., López-Moreno, L.I., Juárez-Velázquez, G.E., Martínez-Villarreal, R.T., Canizales-Oviedo, J.L., Cetina-Umaña, C.M., Perez-Juárez, M.M., González-Moreno, A., Romero-Romero, D., Bello-Pazos, F.D., Aguilar-Orozco, G., Barlandas-Rendón, N.R.E., Maldonado-Anicacio, J.Y., Valadez-Quiroz, A. and Camacho-Ortiz, A. 2020. The Evolution of Antimicrobial Resistance in Mexico During the Last Decade: Results from the INVIFAR Group. Microbial Drug Resistance 26, 1372–1382. https://doi.org/10.1089/mdr.2019.0354

Hermann, J.C., Ridder, L., Höltje, H.-D. and Mulholland, A.J. 2006. Molecular mechanisms of antibiotic resistance: QM/MM modelling of deacylation in a class A β-lactamase. Organic & Biomolecular Chemistry 4, 206–210. https://doi.org/10.1039/B512969A

Humphries, D.L., Scott, M.E. and Vermund, S.H. 2021. Pathways Linking Nutritional Status and Infectious Disease: Causal and Conceptual Frameworks. En: Nutrition and Infectious Diseases. B. Austin (ed.), pp 3-22. Springer.

Kok, M., Maton, L., van der Peet, M., Hankemeier, T. and van Hasselt, J.C. 2022. Unraveling antimicrobial resistance using metabolomics. Drug Discovery Today.

Liguori, K., Keenum, I., Davis, B.C., Calarco, J., Milligan, E., Harwood, V.J. and Pruden, A. 2022. Antimicrobial resistance monitoring of water environments: a framework for standardized methods and quality control. Environmental science & technology 56, 9149–9160.

Martínez, E.B., Arvizu, A.S.V., Ainza, M.L.Á., Álvarez-Hernández, G. and Rangel, M.A.C. 2022. Vigilancia de la resistencia bacteriana en unidades de salud de Hermosillo y Ciudad Obregón, Sonora, México. Biotecnia 24, 132–139.

Navarro-Navarro, M., Robles-Zepeda, R., Garibay-Escobar, A., Ruiz-Bustos, E., Escobar López, R. and Velázquez-Contreras, C.A. 2013. Alta prevalencia de resistencia a los antibióticos en *Escherichia coli* uropatógena comunitaria, detectada en hospitales de Hermosillo, Sonora. Enfermedades Infecciosas y Microbiología 33, 66–70.

Patel, J., Harant, A., Fernandes, G., Mwamelo, A.J., Hein, W., Dekker, D. and Sridhar, D. 2023. Measuring the global response to antimicrobial resistance, 2020-21: a systematic governance analysis of 114 countries. The Lancet Infectious Diseases S1473-3099(22)00796–4. https://doi.org/10.1016/S1473-3099(22)00796-4

Pishtiwan, A.H. and Khadija, K.M. 2019. Prevalence of blaTEM, blaSHV, and blaCTX-M Genes among ESBL-Producing *Klebsiella pneumoniae* and *Escherichia coli* Isolated from Thalassemia Patients in Erbil, Iraq. Mediterranean Journal of Hematology and Infectious Diseases 11, e2019041. https://doi.org/10.4084/MJHID.2019.041

Rello, J., Kalwaje Eshwara, V., Lagunes, L., Alves, J., Wunderink, R.G., Conway-Morris, A., Rojas, J.N., Alp, E. and Zhang, Z. 2019. A global priority list of the TOp TEn resistant Microorganisms (TOTEM) study at intensive care: a prioritization exercise based on multi-criteria decision analysis. European Journal of Clinical Microbiology & Infectious Diseases 38, 319–323. https://doi.org/10.1007/s10096-018-3428-y

Reygaert, W.C. 2018. An overview of the antimicrobial resistance mechanisms of bacteria. AIMS Microbiology 4, 482–501. https://doi.org/10.3934/microbiol.2018.3.482

Rolain, J.M., Abat, C., Jimeno, M.T., Fournier, P.E. and Raoult, D. 2016. Do we need new antibiotics? Clinical Microbiology and Infection 22, 408–415. https://doi.org/10.1016/j.cmi.2016.03.012

Romero, R.M., Acosta, D.D.M. and Ortega, A.B. 2013. Prevalencia y resistencia antimicrobiana de microorganismos aislados en el Centro Oncológico Estatal del ISSEMYM. Revista Mexicana de Patología Clínica y Medicina de Laboratorio 60, 244–251.

Russotto, V., Cortegiani, A., Raineri, S.M. and Giarratano, A. 2015. Bacterial contamination of inanimate surfaces and equipment in the intensive care unit. Journal of Intensive Care 3, 54. https://doi.org/10.1186/s40560-015-0120-5

Salleh, M.Z., Nik Zuraina, N.M.N., Hajissa, K., Ilias, M.I. and Deris, Z.Z., 2022. Prevalence of Multidrug-Resistant Diarrheagenic *Escherichia coli* in Asia: A Systematic Review and Meta-Analysis. Antibiotics (Basel) 11, 1333. https://doi.org/10.3390/antibiotics11101333

Trucco A.O., Prado J. V. and Durán T.C. 2002. Red de vigilancia de resistencia antimicrobiana PRONARES: Informe primer semestre 2001. Revista chilena de infectología 19, 140–148. https://doi.org/10.4067/S0716-10182002019200015

Vélez-Pereira, A. and Caicedo, Y.C. 2014. Aerobacterias en las unidades de cuidado intensivo del Hospital Universitario Fernando Troconis, Colombia. Revista Cubana de Salud Pública 40, 362–368.

Zambrano-Gari, C.C. and Luna-Fontalvo, J.A., 2013. Diversidad microbiana presente en el ambiente de la clínica odontológica de la universidad del Magdalena. Intropica: Revista del Instituto de Investigaciones Tropicales 8, 61–68.

Zarb, P., Coignard, B., Griskeviciene, J., Muller, A., Vankerckhoven, V., Weist, K., Goossens, M., Vaerenberg, S., Hopkins, S., Catry, B., Monnet, D., Goossens, H. and Suetens, C. 2012. National Contact Points for the ECDC pilot point prevalence survey, Hospital Contact Points for the ECDC pilot point prevalence survey, 2012. The European Centre for Disease Prevention and Control (ECDC) pilot point prevalence survey of healthcare-associated infections and antimicrobial use. Euro Surveill 17, 20316. https://doi.org/10.2807/ese.17.46.20316-en

Zúniga-Moya, J.C., Bejarano-Cáceres, S., Valenzuela-Cervantes, H., Gough-Coto, S., Castro-Mejía, A., Chinchilla-López, C., Díaz-Mendoza, T., Hernández-Rivera, S. and Martínez-López, J. 2016. Perfil de sensibilidad a los antibióticos de las bacterias en infecciones del tracto urinario. Acta Médica Costarricense 58, 146–154.