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Bacterial resistance status at a level 2 hospital in Northwest Mexico in 2016

Estatus de la resistencia bacteriana en un hospital de nivel 2 en el noroeste de México en 2016

Ildefonso Guerrero-Encinas[1], Javier N. González-González[1], Manuel E. Reyna-Murrieta[2], Enrique Bolado-Martínez[2], Marco A. López-Mata[3], Gloria G. Morales-Figueroa[1], Cecilia Padilla-Ibarra[4], Luis Quihui-Cota[1]*

[1] Centro de Investigación en Alimentación y Desarrollo, A.C. (CIAD, AC). Departamento de Nutrición Pública y Salud, Sonora, Hermosillo, México.
[2] Departamento de Ciencias Químico Biológicas, Universidad de Sonora, Hermosillo, México.
[3] Departamento de Ciencias de la Salud, Universidad de Sonora, Cd. Obregón, Sonora, México.
[4] Laboratorio clínico del Hospital General del Estado, Sonora, Hermosillo, México.

ABSTRACT

Bacterial infections can be serious and require antibiotic treatment. However, the overuse of antibiotics has led to the development of antibacterial resistance, which can make infections more dangerous. This is a serious problem in Mexico, where published research on antibiotic resistance is limited. This study aimed to estimate the prevalence of antibiotic resistance in bacterial infections at the Hospital General del Estado in Hermosillo (HGE), Mexico so that it can be compared with future information and look for strategies to mitigate this problem. Information was collected from logs registered at the hospital microbiology area in 2016, on bacterial cultures with antibiograms from 2,205 biological samples. These data were obtained from the VITEK® system, which provided information on the bacteria spp., their antibiotic resistance, and the type of antibiotics to which were resistant. *Escherichia coli* (28.8 %), *Staphylococcus aureus* (11.5 %), and *Pseudomonas aeruginosa* (9.8 %) were the most isolated bacteria. The highest prevalence of resistance was found against beta-lactam antibiotics. This study revealed that antibiotic resistance is a serious problem at the HGE. These findings highlight the need for further research on antibiotic resistance in Mexico to design national prevention strategies.
Keywords: Bacterial resistance, Antibiotics, Bacterial infections, Northwest Mexico

RESUMEN

Cuando las infecciones bacterianas son serias requieren antibióticos como tratamiento de elección. Sin embargo, su uso excesivo ha conducido al desarrollo de bacterias resistentes, haciéndolas más peligrosas. Este es un serio problema de salud en México, donde la publicación de investigación sobre este tópico es aún limitada. Este estudio tuvo como objetivo estimar la prevalencia de resistencia a los antibióticos en infecciones bacterianas en el Hospital General del Estado en Hermosillo (HGE), México, y comparase con información futura, estimar tendencias, y buscar estrategias contra este problema. Se recopiló información de 2,205 registros microbiológicos sobre cultivos bacterianos con antibiogramas de muestras de pacientes en 2016. Estos datos se obtuvieron a través del sistema VITEK®, que proporcionó información sobre las especies bacterianas, y su resistencia contra y tipo de antibióticos. Las bacterias más aisladas fueron *Escherichia coli* (28.8 %), *Staphylococcus aureus* (11.5 %) y *Pseudomonas aeruginosa* (9.8 %). Las prevalencias más altas de resistencia se encontraron contra antibióticos beta-lactámicos. La resistencia a los antibióticos es un problema grave de salud en el HGE. Esto resalta la necesidad de investigar más sobre la resistencia a los antibióticos en México, para que las autoridades consideren tal información en el diseño de estrategias preventivas.
Palabras clave: Resistencia bacteriana, Antibióticos, Infecciones bacterianas, Noroeste de México

INTRODUCTION

Bacterial infections can compromise the host's health status, making it necessary to use treatments that help and promote the elimination of the pathogen for the proper recovery of the patient. It is important to mention that the severity of bacterial infections depends on the condition and status of the host, such as age, sex, nutritional status, and the presence of other concomitant pathologies (Humphries *et al*., 2021). Usually, the first-choice treatment against bacterial infections is antibiotics. However, over time its inappropriate use has stimulated bacteria to develop resistance against these drugs (Jernigan *et al*., 2020)

In addition, it has been estimated that for every 100 thousand habitants, infections with antibiotic-resistant bacteria results in 57.9 deaths in Latin America and the Caribbean, 42.0 deaths in North Africa and the Middle East, and 67.7 deaths in Central Europe, Eastern Europe, and Central Asia (Murray *et al*., 2022). This problem is associated with both Gram-positive and Gram-negative bacteria; however, the latter is the most common (Gupta and Datta, 2019). In this way, it has been reported that *Escherichia coli*, *Acineto-*

*Correspondence author: Luis Quihui Cota
e-mail: lquihui@ciad.mx
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bacter baumannii, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*, are the main causes of nosocomial infections resistant to antibiotic treatment (Rello *et al*., 2019).

This bacterial resistance may be due to various defense response mechanisms of the microorganism, which allow them to inactivate drugs through their enzymatic system. It can also occur through the expulsion of the drug by flow pumps or, through the modification of its cell wall, reducing its permeability and avoiding the internalization of antibiotics (Breijyeh *et al*., 2020). In this regard, the increase in infections caused by resistant bacteria implies greater complications in the health of patients, as well as an increase in medical expenses due to the prolongation of convalescence time (Banin *et al*., 2017). For this reason, it is important to have case records of bacterial infections and identify which of them showed unusual responses to antibiotic treatment, to understand this problem and propose solutions that allow us to deal with future events. Antimicrobial resistance in countries like Mexico is difficult to address because of the absence of a regulatory body to effectively control the use and sale of antimicrobials, the prescription and self-medication, and the lack of information available on antimicrobial resistance (INSP, 2022). Similarly, more research is required in health centers located particularly in northwest Mexico. In this context, this work aimed to collect records of bacterial infections and determine the prevalence of bacterial resistance to antibiotics in patients treated at the Hospital General del Estado (HGE) in Hermosillo, Sonora from January to August 2016, to showcasing the updated status and, to encourage future investigations for comparative analysis. This study intends to furnish pertinent evidence to prompt the relevant authorities to implement appropriate measures for controlling this issue.

MATERIAL AND METHODS

To carry out the study, information was collected from the logs of the microbiology area of the HGE from 2,205 registered biological samples, of which, in some cases, more than one bacterium was isolated, keeping data on bacterial cultures with antibiograms of patients older than 18 years, considering the age-group ranges as follows: 18 - 28 (n = 309), 29 - 39 (n = 323), 40 - 50 (n = 475), 51 - 61 (n = 464), 62 - 72 (n = 373), and > 73 (n = 261) years old. The samples consisted of blood, pharyngeal exudate, expectoration, bronchial secretion, catheter tip, tissue, stools, urine, wounds, and their secretions (samples collected with swabs, and transported in microbiological medium Stuart). These data were obtained from the VITEK® system (Biomeireux), which provided information about the identity of the bacteria, their resistance to antibiotics, type of the antibiotic to which were resistant as well as the capacity to produce extended-spectrum beta-lactamases (ESBL).

Information was classified based on the hospital service area from which the samples came; external consultation (EC), emergency room (ER), infectious diseases (IFN), orthopedics (ORT), surgery for men (SURM), medicine for men (MEDM), intensive therapy unit (ITU), medicine for women (MEDW), intensive care unit (ICU), women's surgery (SURW) and hemodialysis (HEM). All the information was collected from January to August 2016. The present study was a cross-sectional, and retrospective aimed to determine the bacterial prevalence by species and hospital area, as well as the percentage of bacterial resistance (% R) to each and type of antibiotic by species, age group, sex, and hospital area. This study was evaluated and approved by the ethics committee of the Hospital General del Estado in Hermosillo, Sonora.

A 2-sided Chi-square test was performed on the data obtained to establish differences in antibiotic resistance between females and males. All the data were analyzed with the STATA package version 2012 at a significance level of $p \leq 0.05$.

RESULTS

Table 1 shows the bacterial species isolated during the study based on rank of prevalence: *E. coli* (28.8 %), *Staphylococcus aureus* (11.5 %), *P. aeruginosa* (9.8 %), *Klebsiella pneumoniae* spp. (7.5 %) and *Staphylococcus hominis* (4.1 %). The hospital area with the highest general prevalence of bacterial species (Table 2) was EC (23.0 %), followed by ER (15.0 %), INF (11.0 %), and ORT (11.0 %). The species with the highest prevalence in EC (48.8 %), ER (38.4 %), SURM (33.0 %), and MEDW (28.6 %) was *E. coli*.

In addition, Table 3 shows data on bacterial resistance to antibiotics. For Gram-negative bacteria a higher resistance to ampicillin (AMP) (85.2 %), ampicillin/sulbactam (SAM) (68.9 %), and cefazolin (CFZ) (61.0 %) was registered. On the other hand, for Gram-positive bacteria a higher resistance to benzylpenicillin (BPE) (87.6 %), AMP (60.7 %), and erythromycin (ERI) (60.4 %) was also estimated. Furthermore, 37 % of ESBL were positive out of 818 records analyzed.

Table 4 shows the prevalence of bacterial species resistance to commonly used antibiotics by service area out of 1,781 records. As before, for BPE the highest prevalence of resistance in the ER (19.0 %) was observed, followed by IFN (14.7 %), ICU (8.1 %), ITU (7.6 %), and HEM (3.9 %). For AMP, a higher resistance was observed in EC (29.8 %) and SURM (9.7 %); and finally, for cefazolin (CFZ) in ORT (17.3 %). In addition, the highest prevalence of ESBL (15.1 %) was observed in EC.

Regarding the information by age groups (Table 5), *E. coli* showed the highest prevalence in patients of all ages, followed by *S. aureus* (10.5 - 13.0 %) and *P. aeruginosa* (7.1 - 13.0 %). However, patients in the age- range 51- 61 years (n = 148) (data not shown) showed the highest prevalence (31.2 %). BPE was the antibiotic to which a high prevalence of resistance was found in patients between 18 and 61 years old (from 84.1 to 91.7 %). On the other hand, the resistance to AMP was the highest (85.3 %) in patients aged 62 and 72 years. In addition, the highest resistance to ESBL was found in patients between 40 - 50 and 62 - 72 years old (39.8 and 39.5 % respectively).

On the other hand, a higher prevalence of infections was observed in males (n = 1,213) than in females (n = 802), being *E. coli* the most frequent in both groups (data not shown).

Table 1. Prevalence of bacterial species isolated and identified from 2,205 biological samples at the Hospital General del Estado in Hermosillo, Sonora, during the January to August 2016 period.
Tabla 1. Prevalencia de especies bacterianas aisladas e identificadas de 2,205 muestras biológicas en el Hospital General del Estado en Hermosillo, Sonora, durante el período de enero a agosto de 2016.

Gram positive bacteria		Gram negative bacteria	
Bacterial species	**Prevalence n (%)**	**Bacteria species**	**Prevalence n (%)**
Staphylococcus aureus	254 (11.5 %)	*Escherichia coli*	634 (28.8 %)
Staphylococcus hominis spp. *hominis*	90 (4.1 %)	*Pseudomonas aeruginosa*	215 (9.8 %)
Enterococcus faecalis	84 (3.8 %)	*Klebsiella pneumoniae* spp. *pneumoniae*	166 (7.5 %)
Staphylococcus epidermidis	73 (3.3 %)	*Enterobacter cloacae* spp. *cloacae*	83 (3.8 %)
Streptococcus mitis	28 (1.3 %)	*Proteus mirabilis*	77 (3.5 %)
Streptococcus parasanguinis	27 (1.2 %)	*Acinetobacter baumannii*	64 (2.9 %)
Streptococcus pneumoniae	21 (0.95 %)	*Citrobacter freundii*	30 (1.4 %)
Staphylococcus lentus	15 (0.7 %)	*Stenotrophomonas maltophilia*	26 (1.2 %)
Enterococcus faecium	13 (0.6 %)	*Morganella morganii* spp. *morganii*	21 (0.9 %)
Kocuria kristinae	13 (0.6 %)	*Klebsiella oxytoca*	18 (0.8 %)
Staphylococcus intermedius	10 (0.5 %)	*Klebsiella aerogenes*	12 (0.5 %)
Staphylococcus warneri	10 (0.5 %)	*Serratia marcescens*	12 (0.5 %)
Streptococcus sanguinis	7 (0.31 %)	*Enterobacter cloacae complex*	10 (0.5 %)
Staphylococcus sciuri	6 (0.3 %)	*Acinetobacter baumannii complex*	8 (0.4 %)
Kocuria rosea	6 (0.3 %)	*Providencia rettgeri*	7 (0.3 %)
Enterococcus gallinarum	5 (0.2 %)	*Raoultella ornithinolytica*	7 (0.3 %)
Aerococcus viridans	4 (0.2 %)	*Pseudomonas luteola*	6 (0.3 %)
Staphylococcus haemolyticus	4 (0.2 %)	*Enterobacter cloacae* spp. *dissolvens*	5 (0.2 %)
Escherichia coli	634 (28.8 %)	*Aeromonas hydrophila*	5 (0.2 %)
Pseudomonas aeruginosa	215 (9.8 %)	*Providencia stuartii*	4 (0.2 %)
Klebsiella pneumoniae spp. *pneumoniae*	166 (7.5 %)	*Burkholderia cepacia*	4 (0.2 %)
		Acinetobacter haemolyticus	4 (0.2 %)
		Achromobacter xylosoxidans	3 (0.1 %)

n = number of bacterial isolates.

Lastly, the prevalence of resistance by sex is shown in Table 6. High resistance to BPE, AMP, and SAM was found (88.8, 81.4, and 67.3 %, respectively) in isolates from female patients (n = 865). Similarly, in male patients (n = 1,340), the highest resistance was also observed to BPE, AMP, and SAM (86.9, 84.9, and 70.2 %, respectively). Thus, the antibiotics to which a significant difference in bacterial resistance was found between sexes were OXA, CFZ, cefoxitin (CTX), ceftriaxone (CRO), aztreonam (ATM), piperacillin/tazobactam (TZP), ciprofloxacin (CIP), amikacin (AMK), nitrofurantoin (NIT), tigecycline (TGY), and linezolid (LZ). On the other hand, a higher percentage of bacterial resistance was found for each one of the mentioned antibiotics in women than in males. Finally, the prevalence of ESBL in females and males was 33.1 and 41.2 % respectively.

DISCUSSION

Currently, reports are indicating that *E. coli*, *S. aureus*, *K. pneumoniae* and *P. aeruginosa,* are the main bacteria causing deaths worldwide (Murray *et al*., 2022), and they were predominant in this study. On the other hand, the Mexican Ministry of Health in 2011 analyzed a total of 48,377 biological samples, and reported *E. coli* with 16.9 % (8,192 samples) as the most isolated bacteria species, followed by the coagulase-negative *Staphylococcus* (*S. hominis*, *S. epidermidis*, *S. saprophyticus*, and *S. haemolyticus*) with 14.0 % (6,771 samples), and *P. aeruginosa* with 10.9 % (5,275 samples) (Arias-Flores *et al*., 2016) followed by the group of Coagulase-negative Staphylococci with 6771 cultures (14 %, which agreed with this study. It has been reported that in countries such as Ethiopia, *E. coli*, *P. aeruginosa*, and *K. pneumoniae*, are the

Table 2. Prevalence of bacterial species isolated and identified from 2,113 biological samples by care services at the Hospital General del Estado in Hermosillo, Sonora, from January to August 2016.
Tabla 2. Prevalencia de especies bacterianas aisladas e identificadas a partir de 2,113 muestras biológicas por servicios de atención del Hospital General del Estado en Hermosillo, Sonora, durante el período de enero a agosto de 2016.

Bacterial species	EC (%)	ER (%)	INF (%)	ORT (%)	SURM (%)	MEDM (%)	ITU (%)	MEDW (%)	ICU (%)	SURW (%)	HEM (%)
E. coli	48.8	38.4	12.8	19.3	23.6	15.8	13.3	28.6	7.5	33.0	11.3
S. aureus	4.3	15.0	9.0	22.3	13.3	8.9	15.6	7.6	15.0	7.4	15.9
P. aeruginosa	7.2	4.2	8.5	12.0	12.0	10.8	12.0	5.0	19.6	18.0	2.3
K. pneumoniae	8.4	6.6	8.1	4.3	8.7	7.6	12.0	5.9	3.7	9.6	2.3
S. haemolyticus	2.0	2.7	12.0	1.7	5.6	12.0	6.3	13.4	6.5	2.1	4.5
S. homini	1.6	4.8	6.4	4.3	2.1	7.0	3.1	5.9	7.5	1.1	9.1
E. faecalis	3.7	5.4	3.0	3.4	4.6	3.8	3.9	3.4	0.0	3.2	0.0
E. cloacae spp. *cloacae*	2.7	3.0	5.6	8.2	1.5	3.8	2.3	3.4	1.9	3.2	18.2
P. mirabilis	3.3	3.9	1.3	3.9	7.2	2.5	4.7	2.5	0.9	3.2	2.3
S. epidermidis	1.4	2.1	3.0	2.6	3.6	2.5	5.5	4.2	0.0	4.3	0.0
A. baumannii	1.2	0.3	5.1	3.0	3.1	6.3	4.7	2.5	9.3	2.1	0.0
C. freundii	1.0	0.6	3.8	1.3	1.5	1.9	0.8	1.7	0.0	0.0	0.0
S. mitis	1.2	1.2	3.4	0.9	0.5	1.3	0.8	1.7	0.9	1.1	2.3
S. parasanguinis	2.3	0.3	3.0	0.4	0.0	1.3	0.8	2.5	0.0	0.0	2.3
S. maltophilia	0.2	1.2	4.3	0.4	0.5	1.3	0.8	0.0	3.7	1.1	0.0
M. morganii	1.8	0.9	0.4	0.4	1.0	2.5	0.0	0.8	0.0	0.0	2.3
S. pneumoniae	1.2	0.9	0.9	0.0	0.0	1.3	2.3	0.8	3.7	0.0	0.0
K. oxytoca	0.4	1.2	0.4	0.0	1.0	1.3	1.6	0.0	0.0	3.2	2.3
S. lentus	1.0	0.6	0.4	1.7	0.0	1.3	0.0	0.0	0.9	0.0	0.0
E. faecium	0.0	0.9	0.9	0.0	1.0	1.3	0.0	0.0	0.9	2.1	0.0
K. kristinae	0.2	0.3	0.4	0.4	0.5	0.6	0.8	2.5	1.9	1.1	0.0
K. aerogenes	0.2	0.0	0.4	0.0	1.5	1.3	1.6	1.7	1.9	0.0	0.0
S. marcescens	1.6	0.6	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0
E. cloacae spp. *complex*	0.4	0.9	0.4	0.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0
S. intermedius	0.8	0.0	0.9	0.4	0.0	0.6	1.6	0.8	0.0	0.0	0.0
S. warneri	0.0	0.0	1.3	2.1	0.5	0.0	0.0	0.0	0.9	0.0	0.0
A. baumannii complex	0.0	0.0	1.3	0.9	0.0	0.0	0.8	1.7	0.0	0.0	0.0
P. rettgeri	0.4	0.3	0.0	0.0	0.5	0.6	0.8	0.8	0.0	0.0	0.0
R. ornithinolytica	0.6	0.0	0.4	0.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0
S. sanguinis	0.6	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.9	0.0	0.0
TOTAL (n)	512	333	237	233	201	158	128	119	107	88	44
	23 %	15 %	11 %	11 %	9 %	7 %	6 %	5 %	5 %	4 %	2 %

EC= external consultation; ER= emergency room; INF= infectious diseases; ORT= orthopedics; SURM= surgery for man; MEDM= medicine for man; ITU= intensive therapy unit; MEDW= medicine for women; ICU= intensive care unit; SURW= surgery for women; HEM= hemodialysis.

Table 3. Prevalence of resistance (% R) of the bacterial species isolated and identified from 2,205 biological samples against the antibiotics used at the Hospital General del Estado in Hermosillo, Sonora, from January to August 2016.
Tabla 3. Prevalencia de resistencia (% R) de las especies bacterianas aisladas e identificadas de 2,205 muestras biológicas frente a los antibióticos utilizados en el Hospital General del Estado en Hermosillo, Sonora, de enero a agosto de 2016.

Drugs		**Gram negative bacteria**	**Gram positive bacteria**
Drug group	**Antibiotic**	**% R**	**% R**
I Beta-lactams			
1. Penicillins	AMP	85.23	60.7
	BPE	ND	87.61
	OXA	ND	54.51
2. Cephalosporins	CFZ	61.05	ND
	FEP	37.37	ND
	CTX	ND	42.18
	CRO	48.02	ND
3. Monobactam	ATM	38.91	ND
4. Beta-lactam/beta-lactamase inhibitors	SAM	68.94	ND
	TZP	30.75	ND
5. Carbapenems	ETP	2.47	ND
	MEM	11.06	ND
II Quinolones	CIP	47.02	45.93
	LVX	ND	42.92
	MFX	ND	31.26
III Aminoglycosides	AMK	8.9	ND
	STR	ND	34.31
	GEN	29.79	21.12
	TOB	33.9	ND
IV Sulfonamide/Trimethoprim	SXT	54.46	28.86
	NIT	46.02	4.57
V Macrolides and Lincosamides	CLI	ND	58.7
	ERI	ND	60.47
VI Tetracyclines/Glycylcyclines	TCY	ND	24.26
	TGY	28.33	1.48
VII Oxazolidone and streptogramin	LZ	ND	0.87
	QXD	ND	14.49
VIII Rifamycins	RIF	ND	14.26
IX Glycopeptides	VAN	ND	0.88
ESBL		NEG* 516 (63 %)	POS* 302 (37 %)

*POS= positive y NEG= negative. Ampicillin (AMP); benzylpenicillin (BPE); oxacillin (OXA); cefazolin (CFZ); cefepime (FEP); cefoxitin (CTX); ceftriaxone (CRO); aztreonam (ATM); ampicillin sulbactam (SAM); piperacillin/tazobactam (TZP); ertapenem (ETP); meropenem (MEM); ciprofloxacin (CIP); levofloxacin (LVX); moxifloxacin (MFX); amikacin (AMK); streptomycin (STR); gentamicin (GEN); tobramycin (TOB); trimethoprim+sulfamethoxazole (SXT); nitrofurantoin (NIT); clindamycin (CLI); erythromycin (ERI); tetracycline (TCY); tigecycline (TGY); linezolid (LZ); quinupristin/dalfopristin (QXD); rifampicin (RIF); vancomycin (VAN); ESBL= extended-spectrum beta-lactamases.

Table 4. Prevalence of resistance (% R) of bacterial species isolated and identified from 1,781 biological samples from different care areas at the Hospital General del Estado in Hermosillo, Sonora, during the January to August 2016 period.
Tabla 4. Prevalencia de resistencia (% R) que presentan las especies bacterianas aisladas e identificadas de 1,781 muestras biológicas en las diferentes áreas de atención del Hospital General del Estado en Hermosillo, Sonora, durante el período de enero a agosto de 2016.

*TX	ORT	SURM	HEM	INF	ITU	EC	ICU	ER
	% R	% R	% R	% R	% R	% R	% R	% R
AMP	9.0	9.7	0.8	8.9	5.5	29.8	4.0	15.0
BPE	14.5	9.2	3.9	14.7	7.6	10.1	8.1	19.0
OXA	6.5	6.1	2.4	12.8	3.7	5.4	6.1	8.2
CFZ	17.3	9.6	2.5	3.5	4.4	2.0	0.7	0.3
FEP	4.4	3.0	0.2	3.4	2.5	22.3	1.1	4.4
CTX	7.5	6.8	0.9	13.2	4.9	5.3	6.2	9.3
CRO	7.3	5.7	0.3	6.5	3.9	13.4	3.3	6.5
ATM	5.4	3.8	0.3	5.6	2.9	12.0	1.7	6.2
SAM	7.3	7.0	0.7	6.1	3.9	29.6	3.4	11.0
TZP	7.7	3.2	0.5	5.3	4.0	3.2	2.4	3.4
ETP	0.2	0.1	0.0	0.1	0.2	0.6	0.0	1.1
MEM	1.6	1.5	0.0	0.7	1.2	2.5	1.2	1.2
CIP	6.0	4.6	1.0	6.4	3.0	14.4	2.7	7.6
LVX	5.0	5.3	1.8	9.9	2.8	3.5	4.2	7.4
MFX	4.0	4.6	1.1	6.8	2.2	2.6	2.4	6.2
AMK	4.0	4.6	1.1	6.8	2.2	2.6	2.4	6.2
STR	3.6	2.4	0.0	7.1	1.2	8.3	1.2	9.5
GEN	4.1	2.4	0.4	3.7	1.9	7.2	1.6	4.8
TOB	5.0	2.8	0.4	3.4	2.2	12.8	1.7	5.0
SXT	5.7	5.3	1.0	6.3	3.3	14.3	3.1	7.2
NIT	4.2	4.3	0.2	4.0	2.7	10.1	2.4	4.4
CLI	7.5	7.7	2.4	12.3	5.0	7.0	4.6	10.8
ERI	7.6	7.4	2.2	13.3	4.2	6.8	5.5	11.6
TCY	1.5	3.1	0.9	3.5	2.0	5.4	1.5	5.0
TGY	3.5	2.9	0.2	2.3	1.5	5.1	1.3	2.6
LZ	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.2
QXD	1.7	2.4	0.2	1.7	1.1	3.1	0.6	3.7
RIF	1.3	0.6	0.4	6.5	0.9	1.1	1.1	1.7
VAN	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.2
ESBL	3.6 %	3.0 %	0.3 %	3.9 %	2.2 %	15.1 %	0.6 %	7.0 %

TX= antibiotic, ampicillin (AMP); benzylpenicillin (BPE); oxacillin (OXA); cefazolin (CFZ); cefepime (FEP); cefoxitin (CTX); ceftriaxone (CRO); aztreonam (ATM); ampicillin sulbactam (SAM); piperacillin/tazobactam (TZP); ertapenem (ETP); meropenem (MEM); ciprofloxacin (CIP); levofloxacin (LVX); moxifloxacin (MFX); amikacin (AMK); streptomycin (STR); gentamicin (GEN); tobramycin (TOB); trimethoprim+sulfamethoxazole (SXT); nitrofurantoin (NIT); clindamycin (CLI); erythromycin (ERI); tetracycline (TCY); tigecycline (TGY); linezolid (LZ); quinupristin/dalfopristin (QXD); rifampicin (RIF); vancomycin (VAN); extended-spectrum beta-lactamases (ESBL); orthopedics (ORT); surgery for man (SURM); hemodialysis (HEM); infectious disease (INF); intensive unit therapy (ITU); external consultation (EC); intensive care unit (ICU); emergency room (ER).

Table 5. Prevalence of resistance (% R) and sensitivity (% S) by age group (years), of bacterial species isolated at the Hospital General del Estado in Hermosillo, Sonora, during the January to August 2016 period, from 2,205 biological samples.

Tabla 5. Prevalencia de resistencia (% R) y sensibilidad (% S) de especies bacterianas aisladas por grupo de edad (años) en el Hospital General del Estado en Hermosillo, Sonora, durante el periodo de enero a agosto de 2016, a partir de 2,205 muestras biológicas.

Antibiotic	(18 - 28)	(29 - 39)	(40 - 50)	(51 - 61)	(62 - 72)	(>73)
	% R	% R	% R	% R	% R	% R
AMP	70.6	80.4	83.2	80.0	85.3	78.0
BPE	91.7	84.1	89.9	85.4	85.1	90.3
OXA	49.5	50.0	55.7	52.8	60.5	66.7
CFZ	67.3	62.6	64.6	62.2	57.1	51.6
FEP	30.5	23.7	37.1	34.2	30.6	30.9
CTX	56.1	51.8	60.7	55.6	63.2	66.7
CRO	54.4	42.4	48.6	49.7	44.0	41.7
ATM	39.8	33.8	43.2	41.0	38.1	34.9
SAM	75.7	68.2	66.5	73.6	67.9	60.5
TZP	44.3	17.6	38.2	27.9	24.3	34.0
ETP	1.9	0.8	0.4	2.2	3.5	2.5
MEM	14.6	11.9	13.5	12.1	7.1	7.7
CIP	41.6	35.8	48.6	49.5	50.3	52.8
LVX	39.2	33.3	44.2	43.8	50.0	53.2
MFX	30.0	19.8	31.9	34.3	36.2	40.3
AMK	13.9	6.9	12.3	10.2	4.3	5.5
STR	15.4	16.7	33.3	34.5	42.1	57.1
GEN	23.7	22.0	28.2	27.5	31.0	28.0
TOB	30.4	27.6	30.1	39.7	38.5	31.4
SXT	49.5	38.3	44.4	51.8	48.4	60.6
NIT	33.0	27.9	30.4	32.3	35.3	36.4
CLI	57.9	54.8	59.4	59.1	56.4	67.7
ERI	61.0	54.0	59.4	59.9	64.9	66.1
TCY	11.0	13.5	30.9	30.7	30.9	32.3
TGY	21.4	16.9	20.3	19.9	22.8	19.7
LZ	0.0	0.0	0.0	1.9	1.3	2.1
QXD	13.4	10.3	10.2	18.4	19.1	16.1
RIF	12.3	14.9	9.8	27.9	14.5	14.6
VAN	0.0	0.8	0.0	0.7	3.2	1.6
ESBL						

Ampicillin (AMP); benzylpenicillin (BPE); oxacillin (OXA); cefazolin (CFZ); cefepime (FEP); cefoxitin (CTX); ceftriaxone (CRO); aztreonam (ATM); ampicillin sulbactam (SAM); piperacillin/tazobactam (TZP); ertapenem (ETP); meropenem (MEM); ciprofloxacin (CIP); levofloxacin (LVX); moxifloxacin (MFX); amikacin (AMK); streptomycin (STR); gentamicin (GEN); tobramycin (TOB); trimethoprim+sulfamethoxazole (SXT); nitrofurantoin (NIT); clindamycin (CLI); erythromycin (ERI); tetracycline (TCY); tigecycline (TGY); linezolid (LZ); quinupristin/dalfopristin (QXD); rifampicin (RIF); vancomycin (VAN); ESBL= extended-spectrum beta-lactamases.

Table 6. Prevalence of resistance (% R) of bacterial species isolated and identified from 865 female patients and 1,340 male patients at the Hospital General del Estado in Hermosillo, Sonora, during the January to August 2016 period.
Tabla 6. Prevalencia de resistencia (% R) de especies bacterianas aisladas e identificadas de 865 pacientes del sexo femenino y 1,340 del sexo masculino en el Hospital General del Estado en Hermosillo, Sonora, durante el período de enero a agosto de 2016.

Drug group	Antibiotic	Female n (% R)	Male n (% R)	*p*
I Beta-lactams				
1. Penicillins	AMP	490 (81.4)	632 (84.9)	0.071
	BPE	191 (88.8)	398 (86.9)	0.478
	OXA	107 (61.1)	207 (51.6)	0.034*
2. Cephalosporins	CFZ	318 (53.2)	533 (66.9)	0.001*
	FEP	186 (31.1)	267 (33.5)	0.335
	CTX	11 (63.4)	222 (55.4)	0.001*
	CRO	257 (43.1)	413 (51.9)	0.001*
3. Monobactam	ATM	186 (35.4)	273 (42)	0.021*
4. Beta-lactam/beta-lactamase inhibitors	SAM	378 (67.3)	479 (70.2)	0.259
	TZP	33 (15.7)	105 (32.8)	0.001*
5. Carbapenems	ETP	14 (2.8)	13 (2.2)	0.497
	MEM	50 (8.8)	95 (12.7)	0.225
II Quinolones	CIP	338 (47.7)	579 (46.1)	0.045*
	LVX	101 (47)	190 (41)	0.146
	MFX	74 (34.3)	138 (29.8)	0.243
III Aminoglycosides	AMK	34 (5.9)	85 (11.3)	0.001*
	STR	137 (33.8)	22 (35.5)	0.798
	GEN	227 (27.9)	330 (26.2)	0.203
	TOB	197 (32.9)	279 (34.2)	0.402
IV Sulfonamide/Trimethoprim	SXT	385 (49.6)	554 (45.5)	0.071
	NIT	236 (29)	436 (34.6)	0.007*
V Macrolides and Lincosamides	CLI	129 (60)	269 (58.1)	0.640
	ERI	137 (63.7)	273 (59)	0.238
VI Tetracyclines/Glycylcyclines	TCY	51 (23.8)	114 (24.6)	0.824
	TGY	127 (15.7)	274 (21.8)	0.001*
VII Oxazolidone and streptogramin	LZ	2 (1.1)	3 (0.8)	0.001*
	QXD	33 (15.3)	65 (14.1)	0.667
VIII Rifamycins	RIF	28 (16)	54 (13.5)	0.430

*Chi-square, significance at level of $p \leq 0.05$. Ampicillin (AMP); benzylpenicillin (BPE); oxacillin (OXA); cefazolin (CFZ); cefepime (FEP); cefoxitin (CTX); ceftriaxone (CRO); aztreonam (ATM); ampicillin sulbactam (SAM); piperacillin/tazobactam (TZP); ertapenem (ETP); meropenem (MEM); ciprofloxacin (CIP); levofloxacin (LVX); moxifloxacin (MFX); amikacin (AMK); streptomycin (STR); gentamicin (GEN); tobramycin (TOB); trimethoprim+sulfamethoxazole (SXT); nitrofurantoin (NIT); clindamycin (CLI); erythromycin (ERI); tetracycline (TCY); tigecycline (TGY); linezolid (LZ); quinupristin/dalfopristin (QXD); rifampicin (RIF); vancomycin (VAN); ESBL= extended-spectrum beta-lactamases.

most common antibiotic resistant-bacteria, suggesting that those bacterial species are the most serious health problem worldwide (Berhe *et al*., 2021). It is recognized that ESBL-producing *E. coli* infections are not necessarily considered as an intra-hospital infection since these have already been reported in outpatients. This may explain the high prevalence of infections registered in EC and ER, suggesting that this type of pathogens may be spreading outside hospitals (Rodríguez-Baño *et al*., 2004).

The findings in this study revealed a high prevalence of bacteria resistant to antibiotics belonging to the beta-lactams group (penicillins and cephalosporins), and to ERI belonging to the macrolides and lincosamides group. In another study carried out in 2017 in 47 health centers and 20 regions of Mexico, a high bacterial resistance to third and fourth-generation cephalosporins (> 50.0 %) and trimethoprim-sulfamethoxazole (> 60.0 %) was reported (Garza-González *et al*., 2019). In addition, such data is like that of this study (47.1 %). β-lactam antibiotics are the choice treatment and they are effective against some pathogenic bacteria (Russ *et al*., 2020). Likewise, some bacteria can produce ESBL, enzymes that confer resistance against β-lactam antibiotics. These enzymes hydrolyze the β-lactam ring of the antibiotic limiting its therapeutic activity (Hermann *et al*., 2005). In agreement to this, an increase in the appearance of bacterial resistant to ceftriaxone, belonging to the group of cephalosporins, has been observed, mainly by *E. coli* and *K. pneumoniae* (Rolain *et al*., 2016). In this regard, these two bacteria are commonly associated with the production of ESBL. *E. coli* and *K. pneumoniae* are frequently found in the human intestine and they spread through feces which implies a public health problem (Cocker *et al*., 2022).

ESBL-producing microorganisms are frequently multi-resistant. So, the SENTRY Antimicrobial Surveillance Program has revealed a prevalence of ESBL-producing *E. coli* and *K. pneumoniae* of 45.0 and 8.5 % in Latin America; 7.6 and 3.3 % in the United States; and 22.6 and 5.3 % in Europe. These bacteria cause infections in hospitalized patients with malnutrition and comorbidities, and carbapenems may be the first choice of treatment because they are resistant to hydrolysis by ESBL-producing bacteria (Navarro-Navarro *et al*., 2011).

A high prevalence of resistance was observed in the ER, IFN and ICU services, with BPE as the antibiotic to which the highest resistance was recorded. It is noteworthy to mention that in the ICU, usually critical state patients with compromised immune systems are accommodated (López-Pueyo *et al*., 2011). A study conducted in 2012 at the Daniel Alcides National Hospital in Peru analyzed 3,149 samples from patients with intra-hospital infections and reported that 29.4 % were ESBL-producing bacteria, and the area with the highest prevalence was EC with 37.42 % (Tejada Llacsa *et al*., 2015). On the other hand, a high prevalence of ESBL in people being attended at external consultation, reinforces the idea that this problem goes beyond intra-hospital infections. It has been reported that in the University of Lagos Medical Centre (n = 350), ESLB-producing bacteria (mainly *E. coli* and *K. pneumoniae*) resistant to AMP were isolated from stool and urine samples of apparently healthy outpatient (Deji-Agboola *et al*., 2020). It is evidenced that antibiotic-resistance genes are spreading outside hospitals and many of these bacteria may be part of the human microbiota emphasizing the seriousness of this problem.

On another hand, the most prevalent bacterium in any age group was *E. coli*, showing the highest prevalence in patients older than 40 years. Previous reports has stated that patients between 60 and 70 years old (Xiamen, China, 2015) suffer infections associated with antibiotic-resistant *A. baumannii* (Huang *et al*., 2018). It has suggested that adult patients might be more susceptible to some bacterial infections than younger patients. The literature has reported that older people may be more susceptible to different pathologies, due to natural physiological changes that may influence the immune system status (Sadighi Akha, 2018).

In this study, a trend of higher prevalence of antibiotic-resistant bacteria was observed with age, which may be an important criterion regarding the sensitivity of some antibiotics. It has been proposed that resistance is more frequent in people over 60 years old in comparison to younger ones, probably associated with the frequent use of catheters and a high occurrence of chronic diseases (Zúniga-Moya *et al*., 2016). Furthermore, a study of 3,149 participants showed that the age group with the highest prevalence of ESBL-producing bacteria was over 65 years old (26.6 %) (Tejada Llacsa *et al*., 2015). However, the high prevalence of resistance to the penicillin group (> 80 %) isolated from all age groups, has suggested that penicillins are no longer effective (Marín and Gudiol, 2003).

On the other hand, a higher number of infections were observed in men as compared to women. It has been reported that, in mammals, males can become more susceptible to infections than females, an event probably associated with variations in the immune response dependent by sex (Klein and Flanagan, 2016). Cases of infections by pathogenic bacteria are more frequent in male than in female. It has been thought that women may have a better immune defense due to an increased response by some cells of the innate immune system (macrophages and dendritic cells) reducing the risk of infection (vom Steeg and Klein, 2016).

On the other hand, sex hormones levels may also play an important role in the function of some immune cells (lymphocytes, macrophages, and dendritic cells). The interaction of sex hormones with some receptors can directly influence signaling processes associated with the production of cytokines, which can vary depending on sex (Kadel and Kovats, 2018). However, this remains unclear. It has also been observed that the presence of ESBL is dependent on age and sex, and is more commonly observed in elderly people and males, so actions should be proposed to attend to the most vulnerable groups (Martin *et al*., 2016).

Currently, the bacterial resistance to antibiotics shows a high variability worldwide. Apparently, the developed countries have shown a lower incidence of this health problem than in some African and Latin-American countries (Health Policy Watch, 2022). For example, in Mexico, a few studies carried out at different hospitals reported a high prevalence of bacterial resistance and it remains unchanged with time, while this problem tends to increase in other countries. This has suggested that strategies to curb this situation in some countries have been somehow established without being monitored, while in others they are urgently required (Patel *et al*., 2023).

Additionally, it is important to consider that the severity of this problem may be greater, because since the 2019 to March 2020 period of the SARS-COV-2 pandemic, an increase of 11.2 % in the consumption of antimicrobials was registered worldwide (Khouja *et al*., 2022). In Mexico, an increase was also recorded in bacterial resistance during this pandemic, with predominant cases of *S. aureus* resistant to OXA, and *K. pneumoniae* resistant to carbapenem (data from 46 centers in Mexico) (López-Jácome *et al*., 2022). In addition, other studies carried out in Northwestern Mexico have suggested that a third of the population resorted self-medication due to the pandemic, however, drugs used were not identified (Torres Soto *et al*., 2022). This situation can change the current context of resistance in this region, so new studies are required to follow up on this problem in the city of Hermosillo, to take actions in real time to prevent a more serious stage.

CONCLUSIONS

Updated information about the prevalence of bacterial species that cause infections in patients of different hospital areas, will allow for the design of hospital prevention and control strategies for *E. coli*, *S. aureus*, *P. aeruginosa*, *K. pneumoniae* spp, *S. haemolyticus*, and *S. hominis* infections, which are commonly isolated from biological samples collected from HGE patients during the study period. On the other hand, the use of antibiotics in hospital patients should be monitored based on their route of administration, dose, treatment extension, and interactions with other medications. Also, special attention should be paid to the management of antibiotics belonging to the β-lactams, as they are the antibiotics against which the highest resistance was found. In addition, it is advisable to monitor the patient effectively complies with his treatment period, to prevent the increase of bacterial resistance and the appearance of multi-resistant strains as evidenced by this work.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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