



NOSOCOMIAL INFECTIONS

Prevalence and antimicrobial resistance of *Escherichia coli* in a Tertiary-level hospital

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Keywords

E. coli • Multiresistant • ESBL

Summary

This study was designed to achieve more effective treatment for patients and to encourage the development of new antibiotics, specifically targeting multidrug-resistant *Escherichia coli*. This bacterium is one of the primary causative agents of hospital-acquired infections (HAI). It is classified as a critical priority pathogen for the development of new antibiotics according to the World Health Organization (2024). In this study, 76 isolates from four bacterial genera were analyzed. *E. coli* was identified as the most prevalent infectious agent with 52% of the isolates, followed by *Klebsiella pneumoniae* (20%), *Pseudomonas aeruginosa* (12%), and *Acinetobacter baumannii* (16%). Internal Medicine was the hospital department with the highest frequency of *E. coli* infections. Sixty-five percent of the samples were derived from urine.

This bacterium was more prevalent in females (57.5%) than in males (42.5%). The highest resistance rates were observed for Ampicillin and Ciprofloxacin, with 90% and 77.5% respectively, while the lowest resistance was found for the Carbapenems Ertapenem, Meropenem, and Aminoglycoside Amikacin, with 22.5%. Twenty-two point five percent of the *E. coli* isolates were classified as resistant, and 77.5% as multidrug-resistant. Sixty-two point five percent were extended-spectrum beta-lactamase (ESBL) producers. All of these isolates resisted Ampicillin, while 4% were resistant to Ertapenem, Meropenem, and Amikacin. *E. coli* was identified as the primary causative pathogen of HAI in the Hospital under study and demonstrated resistance to most currently prescribed antibiotics.

Introduction

Antibiotic resistance is an escalating public health issue, necessitating the establishment of global surveillance networks. The increase in microbial resistance to antibiotics has led to higher morbidity and mortality from infections, prolonged hospital stays, increased antibiotic use, and excessive hospitalization costs [1]. Given this situation, there is a pressing need to understand the prevalence of hospital-acquired infections caused specifically by *Escherichia coli*, which would provide information on resistance profiles in each healthcare institution to enable effective patient treatment and to underscore the importance of developing new antibiotics for multidrug-resistant microorganisms.

A review of the antimicrobial resistance (AMR) commissioned by the UK government posited that antimicrobial resistance could result in 10 million deaths annually by 2050 [2]. It has been estimated that in 2019, 1.27 million deaths were directly attributable to resistance, contributing to 4.95 million deaths associated with bacterial AMR globally. *E. coli*, *Staphylococcus aureus*,

Klebsiella pneumoniae, *Streptococcus pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa* accounted for 929,000 deaths out of the 1.27 million fatalities attributable to resistance, with *E. coli* responsible for the highest number of deaths that year [3].

E. coli is one of the most well-adapted bacterial organisms and versatile pathogens. It causes a variety of human infections, including gastrointestinal diseases and extraintestinal infections [4]. Infections caused by extraintestinal pathogenic *E. coli* (ExPEC) constitute a serious public health issue globally. The most concerning include urinary tract infections, severe neonatal meningitis, serious intra-abdominal infections, and, more rarely, pneumonia, infections of intravascular devices, osteomyelitis, soft tissue infections, or sometimes bacteremia [5]. This bacterium is one of the leading causative agents of hospital-acquired infections, and due to the acquisition of antibiotic resistance mechanisms, it has been classified as a pathogen of public health significance. It is included in the ESKAPE group, which comprises pathogens exhibiting multidrug resistance [6]. *E. coli* is designated

as a critical priority on the list published and updated by the World Health Organization (WHO) in 2024, which categorized priority bacterial pathogens for the development of new antibiotics, emphasizing resistance to third-generation cephalosporins and Carbapenems in this enterobacterium [7].

Materials and methods

STUDY DESIGN

A retrospective descriptive study was conducted on strains isolates between March and December 2019. The distribution of the patients in the database contains a representative demographic coverage of the state. The database used includes patients from multiple regions across the state of Sinaloa and contains key demographic variables, such as age and sex. This statewide geographic distribution, together with the inclusion of basic demographic characteristics, provides demographic coverage of the state population and allows for a representation of patients of Sinaloa.

Data identified for patients and isolates included: age, sex, sample type, tested antibiotic agents, susceptibility testing methods, resistance profiles, and institution type. Individual laboratory techniques performed antimicrobial susceptibility testing using Clinical and Laboratory Standards Institute (CLSI)-approved methods and interpreted results using Food and Drug Administration (FDA)/CLSI breakpoints and interpretive criteria [8].

SELECTIONS OF STRAINS

Hospital-acquired infections were reported over a one-year period at the Culiacan General Hospital “Bernardo J. Gastelum,” and isolates were selected based on the following criteria. First, these isolates corresponded to Gram-negative bacteria associated with more severe complications in hospitalized patients, namely *E. coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii*. Second, these genera are included in the World Health Organization (WHO) list of priority pathogens for the development of new antibiotics. Third, they were the bacterial genera with the most complete susceptibility data available.

The isolates were obtained from urine, sputum, wound, and blood samples from various departments within the aforementioned hospital. We selected isolates belonging to the bacterial genus *E. coli* for our analysis, as this species represents the leading cause of hospital-acquired infections. Inclusion criteria comprised: (i) clinical isolates identified as *E. coli* using automated systems; (ii) isolates associated with hospital-acquired infections, defined as infections occurring ≥ 48 –72 h after hospital admission; and (iii) isolates obtained from hospitalized patients during the study period. Only the first isolate per patient per infectious episode was included. Exclusion criteria included: (i) isolates not identified as *E. coli*; (ii) isolates from infections acquired before hospital admission; (iii) isolates with incomplete susceptibility data or obtained outside the study period.

E. coli isolates were considered as 100% of the samples because, following their selection, the study specifically focuses on the analysis of isolates of this bacterium.

IDENTIFICATION, ANTIMICROBIAL SUSCEPTIBILITY, AND ESBL PRODUCTION

For identification, ESBL production, and susceptibility profiling, automated systems Microscan® and Vitek® were utilized. The susceptibility profile of the *E. coli* isolates was determined against 13 antibiotics from four different families: beta-lactams (Ampicillin, AMP; Cefuroxime, CFX; Ceftriaxone, CRO; Ceftazidime, CAZ; Cefotaxime, CTX; Cefepime, FEP, Ertapenem, ETP; and Meropenem, MEM), aminoglycosides (Amikacin, AMK; Gentamicin, GEN), Fluoroquinolones (Ciprofloxacin, CIP), and Sulfonamides (Trimethoprim and Sulfamethoxazole, SXT). Additionally, the isolates were classified as susceptible (S), Intermediate (I), or resistant (R) according to the CLSI 2021 criteria [8].

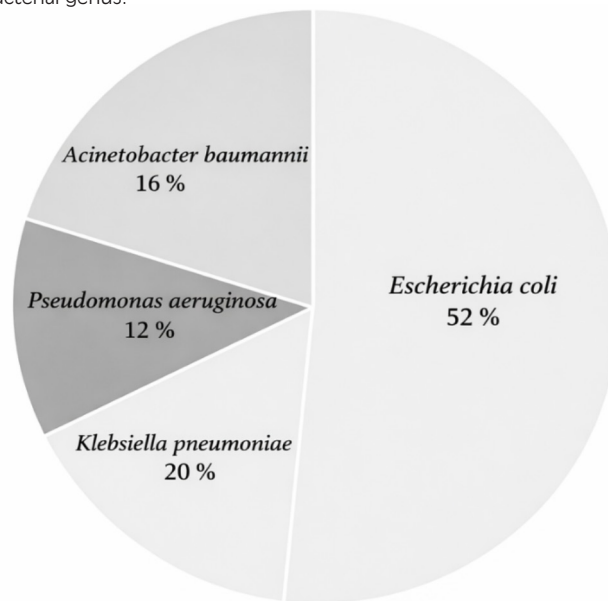
STATISTICAL ANALYSIS

A microbiological and epidemiological analysis was conducted through a descriptive statistical study of qualitative variables. Following the determination of the susceptibility pattern, all data were consolidated in Microsoft Excel®, including resistance by antibiotic and by class, as well as variables such as age, sex, and the hospital department from which the samples were obtained.

Results

A total of 1,860 hospital-acquired infections caused by bacteria were reported in the state of Sinaloa over one year, of which 303 were at the Culiacan General Hospital, “after Gastelum (“Bernardo J Gastelum”) and 76 were analyzed. Bacteria were obtained from the genera: *E. coli* 52% (40 isolates), *Klebsiella pneumoniae* 20% (15 isolates), *Pseudomonas aeruginosa* 12% (9 isolates), and *Acinetobacter baumannii* 16% (12 isolates) as shown in Figure 1. All the isolates were obtained from patients at a third-level Hospital of Culiacan, Sinaloa, “Bernardo J Gastelum”, from samples of urine, sputum, blood, and wounds collected from the services of hemodialysis, internal medicine, pediatric emergencies, traumatology, neurosurgery, outpatient consultations, and emergency care. Of the 76 isolates analyzed, 55.3% (42 isolates) were from male patients and 44.7% (34 isolates) from female patients. According to the patient’s age, 26.3% (20) were between 40 and 59 years old, 23.7% (18) were 60 years or older or had no age record, 22.3% (17) were between 19 and 39 years old, while only 3.95% (3) were patients aged between 0 and 18 years. Regarding the type of sample, 42.1% (32 samples) came from urine cultures, 32.9% (25 samples) from sputum, 13.1% (10 samples) from the wound, 9.2% (7 samples) from blood, and 1.32% (1 sample) from pleural fluid and catheter samples.

Fig. 1. Percentage of Isolates by bacterial genus.



PRESENCE OF *E. COLI* ACCORDING TO AGE, SEX, AND SAMPLE TYPE

Regarding age, infections caused by *E. coli* were most prevalent in patients aged 40-59 years (32.5%). Meanwhile, 25% of patients with *E. coli* infections were between 19 and 39 years old, 22.5% were over 60 years old, and only 5% of patients were between 0 and 18 years old. 15% of patients did not have an age record. The presence of infections caused by *E. coli*, 57.5% of the patients were females, while 42.5% were males. Of all the isolates obtained, 65% were from urine samples, 20% were from sputum, and 7.50% were obtained from blood and wound sources.

E. COLI PRESENCE BY MEDICAL SERVICE AND SAMPLE TYPE

Of the 40 *E. coli* isolates, 40% were obtained from the internal medicine service, 27.5% from external sources, and 10% from neurosurgery and outpatient clinics. Five percent of the isolates originated from the hemodialysis unit, while 2.5% were obtained from the pediatric emergency and traumatology, and general emergency services.

Of the isolates from internal medicine, 56.25% were from urine cultures, 25% from sputum cultures, 12.5% from blood cultures, and 6.25% from wound cultures. Regarding the isolates of neurosurgery, 50% were obtained from sputum cultures, while 25% were from blood and urine cultures. Of external consultation, 75% were from urine cultures and 25% from secretion cultures. Of the hemodialysis area, 100% were from urine cultures. 2.5% of isolates was collected from pediatric emergencies, traumatology, and general emergencies. In pediatric emergencies and traumatology, 100% of the samples were obtained from urine cultures, while in general emergencies, 100% were from wound cultures (Tab. I).

It is noteworthy that 72.5% of all *E. coli* isolates analyzed came from hospitalized patients in the mentioned medical services, while 27.5% were of external origin. Of the external isolates, 81.81% were from urine cultures, and 9.09% each were from sputum and wound cultures.

ANTIBIOTIC SUSCEPTIBILITY PROFILE OF *E. COLI* ISOLATES

The susceptibility profile of 40 isolates was determined against 13 antibiotics from four different families; the isolates are classified as susceptible (S), intermediate (I), or resistant (R) concerning the aforementioned antibiotics.

A total of 40 isolates (100%) are resistant to antibiotics. In beta-lactams, 90% (36 isolates) exhibited resistance to Ampicillin. Resistance rates were 67.5% for Cefuroxime (27 isolates), and 62.5% for Ceftriaxone, Ceftazidime, Cefotaxime, and Cefepime, with 25 isolates. In aminoglycosides, 45% of isolates were resistant to Gentamicin (18 isolates). For fluoroquinolones, 77.5% presented resistance to Ciprofloxacin (31 isolates), while in sulfonamides, 55% showed resistance to Trimethoprim/Sulfamethoxazole (22 isolates) (Fig. 2).

The 2.5% of isolates (one isolate) were resistant to carbapenems, Ertapenem, Meropenem, and the aminoglycoside Amikacin. It is important to note that in third and fourth-generation cephalosporins, over 50% of the isolates exhibited resistance. These data may reflect inappropriate use of this type of antibiotic, although this was not directly evaluated.

ANTIBIOTIC RESISTANCE OF *E. COLI* BASED ON SAMPLE TYPE (40 ISOLATES)

Considering the sample type and the antibiotic resistance of *E. coli*, the following results were determined (Tab. II). Sixty-five percent of samples (26 isolates)

Tab. I. Percentage (%) of *E. coli* presence by medical service and sample type.

<i>E. coli</i> (52 %)	Medical service	% (n)	Sample	% (n)
		Hemodialysis	5% (2)	Urine culture
				100% (2)
Internal medicine		40% (16)	Urine culture	56.25% (9)
			Expectoration culture	25% (4)
			Wound culture	6.25% (1)
			Blood culture	12.5% (2)
				100% (16)
Pediatric emergencies		2.5% (1)	Urine culture	100% (1)
				100% (1)
Traumatology		2.5% (1)	Urine culture	100% (1)
				100% (1)
Neurosurgery		10% (4)	Expectoration culture	50% (2)
			Blood culture	25% (1)
			Urine culture	25% (1)
				100% (4)
External consultation		10% (4)	Urine culture	75% (3)
	Secreción culture		25% (1)	
			100% (4)	
Emergencies	2.5% (1)	Wound culture	100% (1)	
			100% (1)	
External origin	27.5% (11)	Urine culture	81.81% (9)	
		Expectoration culture	9.09% (1)	
		Wound culture	9.09% (1)	
			100% (11)	
Total		100% (40)		100% (40)

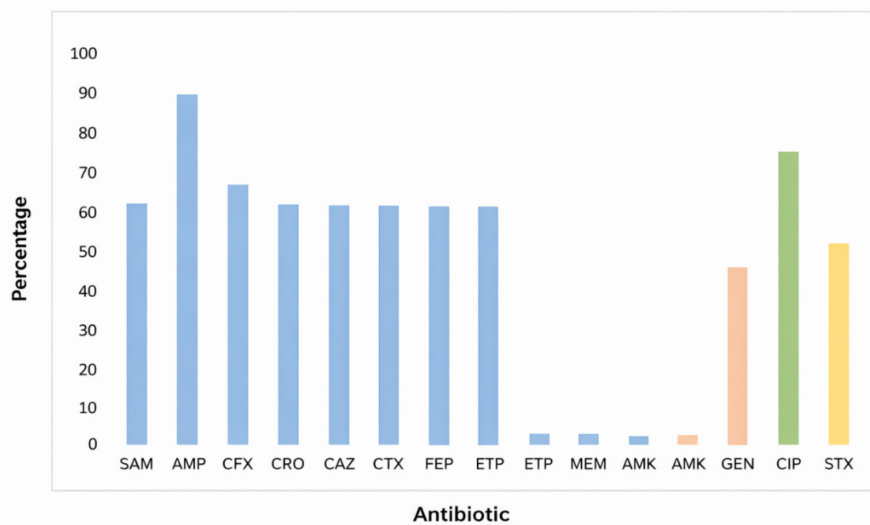
Number of isolates (n). (n=40). 100 % (40).

were collected from urine. The isolates from these samples exhibited 88% resistance to Ampicillin (23 isolates), 62% resistance to Cefuroxime (16 isolates), and 54% resistance to Ceftriaxone, Ceftazidime, and Cefepime (14 isolates). Regarding aminoglycosides, eight isolates exhibited resistance to Amikacin (31%),

and 42% to Gentamicin. While 77% was reported for Ciprofloxacin and Trimethoprim/Sulfamethoxazole (20 isolates). This type of sample did not present resistance to the carbapenems evaluated.

Twenty percent of the samples were collected from sputum, of which 100% exhibited resistance to

Fig. 2. Percentage of antibiotic resistance in *E. coli* (40 isolates).

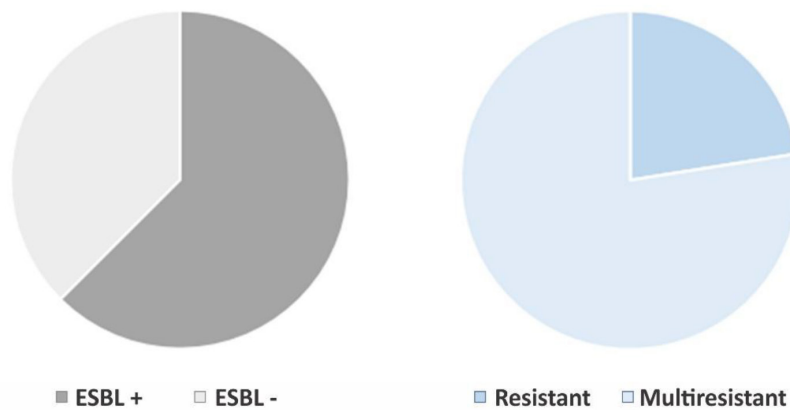


Beta-lactams are shown in blue, Aminoglycosides in pink, Fluoroquinolones in green, and Sulfonamides in yellow. Ampicillin/Sulbactam, SAM; Ampicillin, AMP; Cefuroxime, CFX; Ceftriaxone, CRO; Ceftazidima, CAZ; Cefotaxima, CTX; Cefepime, FEP; Ertapenem, ETP; Meropenem, MEM; Amikacin, AMK; Gentamicin, GEN; Ciprofloxacin, CIP; Trimethoprim and Sulfamethoxazole, SXT.

Tab. II. Antibiotic resistance of *E. coli* based on sample type (40 isolates).

Antibiotic	Sample type			
	Urine	Sputum	Blood	Wound
Ampicilina/Sulbactam	65% (26)	20% (8)	7.5% (3)	7.5% (3)
Ampicilina	88% (23)	100% (8)	67% (2)	100% (3)
Cefuroxima	62% (16)	88% (7)	33% (1)	100% (3)
Ceftriaxona	54% (14)	88% (7)	33% (1)	100% (3)
Ceftazidima	54% (14)	88% (7)	33% (1)	100% (3)
Cefepime	54% (14)	88% (7)	33% (1)	100% (3)
Ertapenem	0% (0)	13% (1)	0% (0)	0% (0)
Meropenem	0% (0)	13% (1)	0% (0)	0% (0)
Amikacina	31% (8)	38% (3)	33% (1)	100% (3)
Gentamicina	42% (11)	38% (3)	33% (1)	100% (3)
Ciprofloxacino	77% (20)	63% (5)	67% (2)	100% (3)
Trimetoprima/Sulfametoxazol	77% (20)	50% (4)	33% (1)	33% (1)

Fig. 3. Percentage of isolates ESBL producer and multiresistant.



Gray graph, ESBL production. Blue graph, resistance classification.
Extended spectrum betalactamases, ESBL. ESBL producer, ESBL +. ESBL no producer, ESBL -.

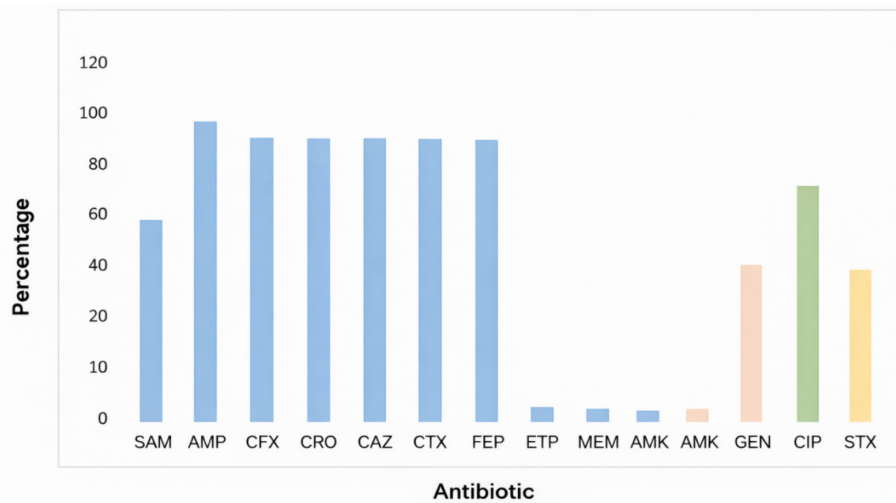
Ampicillin (eight isolates), while 88% (seven isolates) were resistant to cephalosporins evaluated (Cefuroxime, Ceftriaxone, Ceftazidime, and Cefepime). For the aminoglycosides, Amikacin and Gentamicin, resistance rates of 38% were observed (three isolates), while 63% were resistant to Ciprofloxacin (five isolates) and 50% to Trimethoprim and Sulfamethoxazole. Thirteen percent of isolates were resistant to Ertapenem and Meropenem (one isolate).

Seven point five percent of the isolates were derived from blood and wound samples. Among the blood samples, 67% of the isolates (two) presented resistance to Ampicillin and Ampicillin/Sulbactam. Thirty-three percent of the isolates from this sample type were resistant to Cefuroxime, Ceftriaxone, Ceftazidime, Cefepime, Amikacin, Gentamicin, and Trimethoprim/Sulfamethoxazole, while 67% were resistant to Ciprofloxacin. No resistance was observed to the evaluated carbapenems.

The isolates derived from wound samples; one hundred percent demonstrated resistance to Ampicillin, Ampicillin/Sulbactam, Cefuroxime, Ceftriaxone, Ceftazidime, Cefepime, Amikacin, Gentamicin, and Ciprofloxacin. Thirty-three percent of the isolates showed resistance to Trimethoprim/Sulfamethoxazole, while no resistance was observed to Ertapenem and Meropenem.

PERCENTAGE OF RESISTANCE, MULTI-RESISTANCE IN ISOLATED ESBL PRODUCERS

Of the 40 isolates previously mentioned, 25 are ESBL producers, which represent one of the principal mechanisms of resistance associated with *E. coli*. This means that 62.5% of the isolates (25) are ESBL producers, while 37.5% (15) are nonproducers (Fig. 3). Twenty-two point five percent (9 isolates) out of the total evaluated were resistant to at least one of the evaluated antibiotics, while 31 isolates (77.5%) were categorized as multidrug-resistant (Fig. 3) according to the criteria

Fig. 4. Percentage of antibiotic resistance in *E. coli* ESBL producer (25 isolates).

Beta-lactams are shown in blue, Aminoglycosides in pink, Fluoroquinolones in green, and Sulfonamides in yellow. Ampicillin/Sulbactam, SAM; Ampicillin, AMP; Cefuroxime, CFX; Ceftriaxone, CRO; Cefazidime, CAZ; Cefotaxime, CTX; Cefepime, FEP; Ertapenem, ETP; Meropenem, MEM; Amikacin, AMK; Gentamicin, GEN; Ciprofloxacin, CIP; Trimethoprim and Sulfamethoxazole, SXT.

established by Magiorakos et al. [9], indicating resistance to one antibiotic in three or more families of these antimicrobials.

According to the prevalence of resistance among ESBL-producing isolates (Fig. 4), 100% (25 isolates) exhibited resistance to Ampicillin, while over 90% of the isolates were resistant to third and fourth-generation cephalosporins; 96% were resistant to Cefuroxime, Ceftriaxone, Ceftazidime, Cefotaxime, and Cefepime (24 isolates). Sixty-four percent showed resistance to Gentamicin (16 isolates), 84% to Ciprofloxacin (21 isolates), and 56% to Trimethoprim/Sulfamethoxazole (14 isolates). The lowest percentage of resistance was observed against the evaluated carbapenems (Ertapenem and Meropenem) and the aminoglycoside Amikacin, with a resistance rate of 4% (one isolate).

Discussion

Hospital-acquired infections represent a global health issue that escalates healthcare costs and promotes the selective emergence of multidrug-resistant microorganisms. Certain pathogenic species exhibit resistance and are frequently found in hospital settings. *E. coli* is one of the primary causative agents of HAI. Previous studies reported positive culture results for nosocomial infections by the Hospital Epidemiological Surveillance System of the Mexican Social Security Institute, identifying *E. coli* as the most frequently isolated microorganism and of greatest epidemiological relevance, accounting for 16.9% of the total of infections, followed by coagulase-negative *Staphylococcus* and *Pseudomonas aeruginosa* [10]. In this study, it was found that *E. coli* was the main causative agent of infections,

responsible for 52% of total infections, followed by *Klebsiella pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa*. Our results are comparable to those reported by the Epidemiological Bulletin of Healthcare-Associated Infections in Mexico [11], from July to August 2023, *E. coli* was categorized as the principal causative agent of HAI. In the state of Sinaloa [12], in January 2025, this bacterium was the second most prevalent microorganism responsible for hospital infections, accounting for 11.24% of total infections, following *Acinetobacter baumannii* with 13.48%.

Of a total of 40 *E. coli* isolates studied, 40% (16 isolates) originated in the internal medicine department. Notably, this department yielded the majority of the sample types analyzed in this study, including urine, sputum, wound, and blood (Tab. II). Our results are comparable to a related study at the Bajío National Medical Center [13], where the largest number of samples originated in the Internal Medicine department, primarily urine cultures, followed by secretions and blood cultures. These data could reflect a correlation between the hospital area and the types of samples analyzed. Urine samples have been reported as the most frequent, consistent with Chuquisapon et al. [14], with 53.7% of a total of 67 samples, followed by blood samples and bronchial secretions, also belonging to internal medicine.

According to the origin of the samples by sex, 57.50% were obtained from females (23 isolates), whereas 42.5% (17 isolates) were obtained from males. Recent data have reported a higher frequency of *E. coli* in females, specifically among hospitalized patients. Our findings are consistent with those reported by Lopez-Maman [15], who reported the presence of *E. coli* in patients at the Northern Hospital in Bolivia, highlighting

a greater frequency of this bacterium in female patients compared to *Klebsiella pneumoniae*. Notably, the frequency of *E. coli* is higher in females than in males; these results may reflect a correlation between the most frequent sample type (urine) and the presence of *E. coli* in women, as this genus is more commonly associated with urinary tract infection. The higher prevalence of urinary tract infections in women is primarily explained by anatomic conditions: first, the urethra and perianal area are closer together; second, the urethra is shorter in females, reducing the distance that bacteria must travel to reach the bladder; and third, women experience hormonal fluctuations that can disrupt natural defense mechanisms, such as changes in vaginal acidity [16]. Regarding the age groups most affected by *E. coli* infections, similar data to this work have reported a higher prevalence of this bacterium in individuals over 50 years old, likely due to anatomical, physiological, or pathological changes [17]. In this study, it was determined that 32.50% of patients infected with this bacterium were in the age range of 40 to 59 years, and 22.5% were 60 years or older.

Regarding the resistant percentages to the 13 antibiotics belonging to four families of these medications, the results of 40 isolates studied are comparable to those reported by the University Plan against Antimicrobial Resistance (PUCRA) [18], in conjunction with data reported by Garza et al. [19] from the Thematic Network for Collaboration and Surveillance of Antimicrobial Resistance (INFIVAR) in 2019. Where 86% of isolates were resistant to Ampicillin, and 62.5% resistant to Ceftriaxone and Cefepim. The lowest resistance percentages reported by PUCRA were for Meropenem (0.7%), which coincides with our isolates, as we also observed the lowest resistance for this antimicrobial at 2.5%. The low percentages of resistance to carbapenems may be attributed to their classification as a last-resort treatment. However, in some countries, they are no longer effective in more than half of patients with *K. pneumoniae* infections due to resistance. Factors contributing to resistance include the excessive and indiscriminate use of antibiotics, lack of access to clean water, and inadequate disease prevention and control measures [19].

Considering the type of sample and the resistance of *E. coli*, resistance percentages varied. The 65% of the samples were collected from urine (65%). It is important to note that when a urinary tract infection occurs due to *E. coli*, some antibiotics, such as Trimethoprim, are commonly used. According to the results, more than 70% of isolates from this type of sample are resistant to this antibiotic. The high rates of resistance could be attributed to the fact effective drugs are becoming scarce. The resistance rate to Ciprofloxacin, also used to treat urinary infections, ranged from 8.4% to 92.9% for *E. coli* and from 4.1% to 79.4% for *K. pneumoniae* in countries that reported data to the Global Antimicrobial Resistance Surveillance System (GLASS) [20]. Twenty percent of the samples were collected from sputum. In cases of bacterial infections such as pneumonia caused by *E. coli*, third and fourth-generation cephalosporins

are typically prescribed. According to the World Health Organization's updated list of priority pathogens resistant to antibiotics in 2024 [7], *E. coli* is classified as a critical priority due to its resistance to Carbapenems and the aforementioned cephalosporins. Twenty-five countries, territories, and regions reported data to the GLASS on sepsis due to methicillin-resistant *Staphylococcus aureus* (MRSA), and 49 countries provided data on sepsis caused by *E. coli*. The median resistance rate observed for MRSA was 12.11%, while for third-generation cephalosporin-resistant *E. coli*, it was 46% [21].

Sixty-two point five percent of our studied isolates were ESBL producers, comparable to a related study in southern Mexico, where 50% of the isolates were producers of these enzymes [13]. This increases the risk of infections resistant to cephalosporins, which leads to a high number of complications for hospitalized patients [22-24].

Our data show a 90% of resistance rate to Ampicillin and 56% to Trimethoprim/Sulfamethoxazole, whereas resistance rates of 40% to Ampicillin and 35.1% to Trimethoprim/Sulfamethoxazole have been reported in an outpatient study conducted in the central region of the state of Sinaloa [25]. Based on these findings, we suggest that resistance rates may vary depending on the origin of the isolates; however, a consistent pattern is often observed in which isolates are resistant to at least one antibiotic among those evaluated.

Jaqueti et al. [26] reported 66.7% and 4% of resistance to Gentamicin and Amikacin, respectively, in ESBL-producing *E. coli* strains; while our isolates exhibited a resistance of 64% to Gentamicin and 4% to Amikacin, indicating a notable difference in resistance to this aminoglycoside. This discrepancy may be due to variations in antibiotic prescribing practices across different regions of the world. For instance, the mentioned study was conducted in Madrid, Spain, where the Madrid Medical Association has recently called for awareness regarding the rational use of antibiotics to address multidrug-resistant bacteria, which are responsible for approximately 4,000 deaths annually in Spain and over 35,000 in Europe [27].

We observed that in isolates that are ESBL producers, there is a higher percentage of resistance to beta-lactams compared to the isolates in general. The presence of ESBL may be associated with an increased resistance rate to other antibiotic classes, although this was not directly evaluated. This is related to the fact that ESBLs have traditionally been described as being encoded on extrachromosomal elements. These genes, along with those that encode resistance to other antimicrobials, may reside on the same conjugative plasmid and, therefore, are transmitted together from one microorganism to another, conferring a multidrug resistance profile [28].

Hospital-acquired infections are a global public health problem that is increasing with the acquisition of antibiotic resistance. *E. coli* is one of the main causative agents of these infections, exhibiting resistance primarily to third and fourth-generation cephalosporins, affecting the entire population, prolonging patient hospitalization, and bringing about economic impact. Monitoring the

presence of this bacterium and its resistance profiles in hospitals is of utmost importance to provide each patient with the appropriate treatment and also to provide information highlighting the importance of developing new antibiotics to treat infections caused by such microorganisms.

Conclusion

E. coli was identified as the most prevalent infectious agent with 52% of the isolates, followed by *Klebsiella pneumoniae* (20%), *Pseudomonas aeruginosa* (12%), and *Acinetobacter baumannii* (16%).

Internal medicine was the hospital department with the highest frequency of *E. coli* infections, predominantly in urine samples. Of the patients affected, 57.5% were female, and 42.5% were male.

The highest resistance rates were observed for Ampicillin and Ciprofloxacin, with 90% and 77.5% respectively, while the lowest resistance was found for the Carbapenems Ertapenem, Meropenem, and Aminoglycoside Amikacin, with 2.5%.

Twenty-two point five percent out of the total evaluated were resistant to at least one of the evaluated antibiotics, while 31 isolates were categorized as multidrug-resistant. Sixty-two point five percent of the isolates are ESBL producers, while 37.5% (15) are nonproducers. An increase in resistance was observed in ESBL-producing isolates, 100% (25 isolates) exhibited resistance to Ampicillin, while over 90% of the isolates were resistant to third and fourth-generation cephalosporins, and 84% to Ciprofloxacin.

Due to the emerging problem of antibiotic resistance, our work presents data that emphasize the importance of understanding the prevalence of infections, in this specific case of *E. coli*, to prescribe the appropriate treatment and underline the need for the development of new antibiotics.

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Conflicts of interest statement

The authors declare that there are no conflicts of interest that may have influenced the work presented in this article.

Authors' contributions

GGVR designed the research, performed the microbiological analysis, and wrote the article. YPAS created the tables and conducted the literature review. MEBF collected data. SBF collected and provided data.

SPDC performed the literature review. EHG reviewed the data analysis. DMM created figures. DCG performed the final manuscript editing. JRP coordinated the research. All authors reviewed, read, and approved the manuscript, and provided feedback and contributions to the final work.

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