Egyptian Journal of Medical Microbiology Volume 35 / No.3 / July 2026 xxx-xxx Online ISSN: 2537-0979

ORIGINAL ARTICLE

Navigating Resistance: Building an Enhanced Antibiogram for Local Healthcare in Saudi Arabia

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Key words:
Antimicrobial resistance; Antibiotics; Multi-drug resistance organisms (MDROs); Enhanced antibiogram

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ABSTRACT

Background: *The antibiogram is an essential resource for institutions to track changes in antimicrobial resistance and to guide empirical antimicrobial therapy.* ***Objectives:*** *The aim of this study is evaluation of the antibiotic sensitivity patterns for organisms isolated from clinical specimens across various hospital sectors.* ***Methodology:*** *The antibiotic sensitivity test (AST) of isolates was tested by Kirby-Bauer disc diffusion method and interpreted in accordance with the national committee for clinical and laboratory standards guidelines M39. A total of 561 samples (60.6% from Outpatient (OPD), and 39.4% from Inpatients/ICU) were included.* ***Results:*** *The most frequent Gram-ve isolates were E. coli (36.8 %) and K. pneumoniae (12.9 %) in OPD, and K. pneumoniae (26.2%) and P. aeruginosa (13.9 %) in Inpatient/ICU. For Gram+ve isolates, Staphylococcus aureus was predominant in both settings (13.5% &14.5%) for OPD and Inpatient respectively, with Streptococcus agalactiae also prevalent in OPD (18.8%). Multi-drug resistance organisms (MDROs) were more common in ICU settings. Resistance was significant in E. coli, K. pneumoniae, and Pseudomonas against certain beta-lactams, while Amikacin, Gentamicin, Imipenem, Meropenem, and Colistin remained effective. S. aureus (including MRSA) and Enterococcus faecalis were highly sensitive to daptomycin, vancomycin, linezolid, and teicoplanin. Meropenem, Tigecycline Amikacin, Gentamicin, and Imipenem exhibited high sensitivity across all specimen types in contrast to Ampicillin species.* ***Conclusion:*** *Data from enhanced antibiogram revealed the variability of antibiotic sensitivity by specimen type and site and the prevalence of MDROs in ICU settings. Therebefore, there is a need for continuous monitoring resistance trends and tailoring the local hospital AMS program.*

INTRODUCTION

Antibiotics have played a crucial role in revolutionizing medicine by providing potent remedies for infections caused by bacteria that were previously incurable and frequently lethal[1]. Since the beginning of the twentieth century, when penicillin was discovered, antibiotics have prevented millions of deaths and enabled major medical advancements, including organ transplants and routine surgeries[2]. However, despite their obvious importance, antibiotic overuse and abuse in both human and animal medicine has resulted in an alarming increase in resistance to antibiotics, which is now one of the most pressing health issues worldwide. In addition to making patient care more difficult, the emergence of antibiotic-resistant illnesses poses a threat to undo decades of advancements in medicine[3].

Antimicrobial resistance (AMR) is a global problem that necessitates employing a targeted approach to treatment to reduce inappropriate prescribing of antimicrobials and to conserve the efficacy of antimicrobials[4,5]. By 2050, it is anticipated that AMR will contribute to approximately 1.91 million attributable deaths and 8.22 million associated deaths annually[6]. In 2019, Saudi Arabia (SA) ranked 99th out of 204 countries for the lowest age-standardized mortality rate related to AMR, with 2,500 attributable deaths and 9,100 associated deaths reported[7]. Recognizing this, the Saudi National Strategy for Combating Antimicrobial Resistance (2022–2025) aims to optimize antimicrobial use in both human and animal health sectors[8]. It is commonly utilized to monitor recent antimicrobial susceptibility patterns in order to guide empirical antimicrobial therapy selection[9]. Different types of cumulative antibiogram reports can also be compiled at the regional, national, and global levels to estimate susceptibility rates in geographic regions, document trends in evolving microbial populations, and recognize the appearance and spread of emerging antimicrobial resistance threats. An enhanced antibiogram is a report

where the (AST) percent further stratified using specific parameters (e.g., specimen source-specific or patient location antibiogram), and multifacility antibiograms aggregate data from multiple facilities. Once an institution develops an accurate and reliable cumulative antibiogram, institutions should consider exploring the generation of an enhanced antibiogram[10]. Several studies have evaluated different approaches to enhanced antibiogram reporting to improve the functionality of the traditional cumulative antibiogram[11,12].

This study aims to examine and assess the antibiotic susceptibility profiles of various bacterial isolates obtained from clinical specimens across different hospital departments. The primary objective is to ascertain the prevalence of multi-drug resistant organisms (MDROs) and the efficacy of routinely utilized antibiotics in both Outpatient (OPD) and Inpatient/ICU environments. The study aims to clarify the variability of antibiotic resistance patterns and to inform strategies for improving hospital-based antimicrobial stewardship programs.

METHODOLOGY

Study design and setting

This was a 16–month retrospective cross-sectional study conducted was conducted at the Microbiology Department, Ibn Sina College Hospital (ISCH), Jeddah, Saudi Arabia, over 18 months (January 2024–June 2025). ISCH is a general teaching hospital located in Jeddah, SA. The hospital has a bed capacity of 100. Demographic data (age, gender, and nationality), type of microorganism involved and antibiotic sensitivity/resistance pattern of infection-suspected cases, were retrieved from the medical records. Patients who were taking antibiotics or had recently taken antibiotics during the previous 2 weeks at the time of sample collection were excluded. Patients presenting inadequate demography and history of antimicrobial use were also excluded.

Standard Methods of the microbiological lab at ISCH

For samples transportations, samples were usually transported to the central lab within 30 min of collection. Samples were then transported to a microbiological lab by reinserting swabs into test tubes filled with 0.5 mL of sterile normal saline. After that, specimens were processed and cultured following standard techniques used in medical microbiology lab[13]. For pathogen identification, colonies formed were further processed using morphology, Gram staining, and biochemical reaction[13]. Antibiotic susceptibility testing of the detected isolates were performed using the Kirby Bauer disc diffusion method and observations were interpreted in accordance with guidelines set by the National Committee for Clinical Laboratory Standards[14]. A pathogen that is resistant towards 2 or more classes of antibiotics is termed a multidrug-resistant pathogen (MDR)[15]. By dividing the number of susceptible/resistant isolates by the whole number of tested isolates, the sensitivity/resistance rates of specific bacterial isolates to each tested antibiotic agent were calculated.

Ethics

The study protocol was approved by the Institutional Review Research Committee at ISNC and conducted in accordance with the Declaration of Helsinki (Protocol Identification: 087MP/EC-27052024).

Statistical analysis

All retrieved data will be initially recorded into an Excel sheet (Microsoft Corporation, Redmond, WA) and exported to IBM SPSS Statistics for Windows, version 22 (IBM Corp., Armonk, N.Y., USA) for statistical analysis. Frequency and percentages will be used to present categorical data. Chi square or fisher exact tests will be performed to compare the culture positivity, proportion of bacterial isolates and resistance pattern with patients' gender and nationality. Analysis will consider the level of significance at a p-value of ≤ 0.05.

RESULTS

Demographic data

The present study included 561 patients during the whole year of 2023 with culture results of their first bacterial isolates during seeking medical advice in Ibn Sina College Hospital. The patients were divided into 2 groups; Outpatient clinic (OPD) group comprised of 340 (60.6%) and Inpatient/ICU group involved 221 (39.4%) patients.

The median age was higher in Inpatient/ICU group (58 years) than of OPD group (34 years) with statistical significance p value < 0.001. Age was divided into 3groups; child group $\leq$ 18 years old, adult >18<65 and elderly adult $\geq$ 65. The adult group is prominent in OPD while elderly adult was prevalent in inpatient/ICU group with a statistical significance p value < 0.001 **(Table 1)**.

The included patients were 433 (77.2%) females and 128 (22.8%) males. Males were predominant in Inpatient/ICU group while females were eminent in OPD with a statistical significance p value < 0.001 **(Table 1).**

Table 1: Demographic data

		Inpatients/ICU N=221 (39.4%)	OPD N= 340 (60.6%)	p-value*
		N (%)	N (%)	
Gender	Females	112 (50.7%)	321 (94.4%)	<0.001
	Males	109 (49.3%)	19 (5.6 %)	
Age group	Children (≤ 18)	24 (10.9%)	24 (7.1%)	<0.001
	Adults (>18<65)	110 (49.8%)	309 (90.9%)	
	Elderly adults (≥ 65)	87 (39.4%)	7 (2.1%)	

**p-value ≤ 0.05 is statistically significant*

Culture results according to patient location

Gram negative bacteria were prominent in Inpatient/ICU group while Gram positive cultures were eminent in OPD with a statistical significance p value < 0.001.

E. coli and *K. pneumonia* were the most frequent isolated Gram-negative organisms in OPD group. But *K. pneumonia* and *P. aeruginosa* were the prominent Gram-negative organisms detected in Inpatient/ICU group **(Table 2)**.

Staph. aureus was the most eminent isolated Gram-positive in Inpatient/ICU group. In OPD group; *Staph. aureus* and *Strept. agalactica* were representatives of the highest percentage of Gram-positive isolates **(Table 2)**.

Prevalence of organisms according to age group

Regarding Gram-negative organisms; *Acinetobacter* species, *P. aeruginosa*, *Providencia stuartii*, *Proteus* species, *Citrobacter koseri* were prevalent in elderly adults. *Enterobacter* species, *S. maltophilia* were isolated mainly from children. *E. coli* was eminent in adult cultures with significant statistical difference p< 0.001 **(Table 3)**.

Regarding Gram-positive organisms; *Enterococcus faecalis* were prominent in elderly adults. *Staph. aureus*, *Strept. agalactica* were prevalent in adult cultures with statistical significance p <0.001**(Table 3)**.

Table 2: Culture results according to patient location

Location	**OPD (n=340)**		**Inpatient/ICU (n=221)**		**p value***
Isolates	**N**	**%**	**N**	**%**	
Gram**-ve organisms**	199	58.5	168	76	
Escherichia coli	125	36.8%	26	11.8	<0.001
K. pneumoniae	44	12.9%	58	26.2%	
Klebsiella oxytoca	1	0.3%	-	-	
P. aeruginosa	10	2.9%	30	13.6%	
Enterobacter species	13	3.8%	13	5.9%	
Proteus species	2	0.6%	16	7.3%	
Acinetobacter species	2	0.6%	18	8.2%	
Citrobacter koseri	3	0.9%	1	0.5%	
Serratia marcescens	-	-	1	0.5%	
Providencia stuartii	-	-	3	1.4%	
Stenotrophomonas maltophilia	-	-	2	0.9%	
Gram+ve organisms	141	41.5	53	24	
Staph. aureus	46	13.5%	32	14.5%	<0.001
Staph. epidermidis	-	-	2	0.9%	
Staph. hemolyticus	-	-	1	0.5%	
Enterococcus fecalis	25	7.4%	11	5.0%	
Strept. agalactica	64	18.8%	5	2.3%	
Strept. pyogens	5	1.5%	1	0.5%	
Sterpt. pneumoniae	-	-	1	0.5%	
Strept. anginosus	1	0.3%	-	-	

**p-value ≤ 0.05 is statistically significant. Gram-ve: Gram negative. Gram+ve: Gram- positive*

Table 3: Prevalence of organisms according to age group

Gram stain	*Organisms*	Age groups			p-value*
		Children (≤18) N=48	Adults (>18<65) N=419	Elderly (≥ 65) N=94	
Number of Gram-ve **isolates**		35	256	76	
Gram-negative **organisms (n=367)**		**N (%)**	**N (%)**	**N (%)**	
	Acinetobacter species	1(2.9%)	11 (4.3%)	7 (10.5%)	<0.001
	Citrobacter koseri	0(0.0%)	2 (0.8%)	2 (2.6%)	
	E. coli	12(34.3%)	124 (48.4%)	15 (19.7%)	
	Enterobacter species	6(12.5%)	17 (4.1%)	2 (2.1%)	
	K. oxytoca	0(0.0%)	1 (0.4%)	0 (0.0%)	
	K. pneumoniae	8(22.9%)	70 (27.3%)	24 (31.6%)	
	P. aeruginosa	4(11.4%)	21 (8.2%)	15 (19.7%)	
	Proteus species	2(5.7%)	9 (3.5%)	7 (9.2%)	
	Providencia stuartii	0(0.0%)	1 (0.4%)	2 (2.6%)	
	S. maltophilia	1(2.9%)	0 (0.0%)	1 (1.3%)	
	Serratia marcescens	1(2.9%)	0 (0.0%)	0 (0.0%)	
Number of Gram+ve isolates		13	163	18	
Gram-positive isolates organisms (n=194)		**N (%)**	**N (%)**	**N (%)**	
	Enterococcus fecalis	0(0.0%)	31 (19.0%)	5 (27.8%)	<0.001
	Staph. aureus	8(61.5%)	62 (38.0%)	11 (61.1%)	
	Strept. pneumoniae	1(7.7%)	0 (0.0%)	0 (0.0%)	
	Strept. agalactica	2(15.4%)	65 (39.9%)	2 (11.1%)	
	Strept. anginosus	0(0.0%)	1 (0.6%)	0 (0.0%)	
	Strept. pyogenes	2(15.4%)	4 (2.5%)	0 (0.0%)	

**p-value ≤ 0.05 is statistically significant. Gram-ve: gram negative.* Gram+ve: *gram positive. E. coli: Escherichia coli. K. oxytoca: Klebsiella oxytoca. K. pneumonia; Klebsiella pneumonia. P. aeruginosa; Pseudomonas aeruginosa, Staph. aureus; Staphylococcus aureus. S. maltophilia; stenotrophomonas maltophilia. Strept. agalactica; Streptococcus agalactica. Strept. anginosus ; Streptococcus anginosus. Strept.pneumoniae; Streptococcus pneumoniae. Strept. pyogenes; Streptococcus pyogenes.*

Antibiotic sensitivity according to patient location

Sensitivity of Gram negative organisms in Inpatient/ICU sector

According to M39 CLSI Guideline, color coding of antibiotic sensitivity was given as green for more than 80 % sensitivity, red for less than or equal 60% and yellow for the sensitivity in between (1). Many of isolated Gram negative organisms in Inpatient/ICU group were multi drug resistance organisms (MDRO). Amikacin was sensitive by 100% in Proteus species and *E. coli*, by 96.7% in *Pseudomonas aeruginosa* and by more than 60% in *K. pneumonia* and Enterobacter species. Colistin was sensitive by >70% in all except in Proteus species was mostly resistant. Tigecyclin was sensitive > 69% in most isolates excluding Proteus species and *P. aeruginosa*. However, *K. pneumoniae* was highly resistant, with most antibiotics showing sensitivity in less than 80% of cases, except for tigecycline **(Table 4)**.

For sensitivity >80 %; Aminoglycoside antibiotics including Gentamicin and Tobramycin were most frequent sensitive in *P. aeruginosa* and *E. coli* isolates. Impinenm, Meropenem and Nitrofurantoin were detected also with this sensitivity in *E.coli* isolates **(Table 4)**.

Sensitivity of Gram positive organisms in Inpatient/ICU sector

The most evident Gram positive organism detected in Inpatient/ICU sector was Methicillin resistant *Staph aureus* (MRSA) by 68.7%, while vancomycin resistant *Staph. aureus* (VRSA) was 31.2%. Teicoplanin by > 90% and linezolid >85% were the most sensitive antibiotics by *Staph. aureus* isolates **(Table 4)**.

Regarding vancomycin resistant enterococcus (VRE) was only 9.1%. Amox/K, Imipenem, Teicoplanin and vancomycin were the most sensitive antibiotics by > 80% in the enterococcus species **(Table 4)**.

Table 4: Antibiotic sensitivity in Inpatient/ICU sector

Antibiotic for Gram negative	***K. pneumonia***	***Pseudomonas aeruginosa***	***E. coli***	**Acinetobacter species**	**Proteus species**	***Enterobacter* species**	***Antibiotic for Gram positive***	***Staph. aureus***	***Enterococcus fecalis***
Number of G (-) isolates (168)	N=58	N=30	N=26	N=18	N=16	N=13	Number of G (+) isolates (53)	N=32	N=11
	%	%	%	%	%	%		%	%
Amikacin	69	96.7	100	66.7	100	69.2	Amox/K	31.3	81.8
Amox/K	48.3	3.3	65.4	11	37.5	7.7	Ampicillin	3.1	81.8
Ampicillin	0	3.3	42.3	5.6	31.3	7.7	Azithromycin	40.6	18.2
Amp/Sulbactam	34.5	6.7	53.8	50	43.8	23.1	Cefoxitin	31.3	18.2
Aztreonam	36.2	43.3	38.5	5.6	25.0	15.4	Ciprofloxacin	28.1	54.5
Cefazolin	32.8	3.3	50	0	37.5	7.7	Clindamycin	59.4	18.2
Cefepime	36.2	70	57.7	38.9	50.0	46.0	Daptomycin	71.9	90.9
Cefotaxime	36.2	3.3	50	5.6	56.3	15.4	Erythromycin	40.6	36.4
Cefotaxime/K C	51.7	0	88.5	11	62.5	38.5	Fosfomycin	62.5	63.6
Cefoxitin	50	3.3	76.9	0	81.0	15.4	Fusidic acid	25.0	27.3
Ciprofloxacin	50	70	57.7	38.9	68.8	69.2	Gentamicin	71.9	0
Gentamicin	63.8	83.3	84.6	50.0	62.5	76.9	Imipenem	31.3	81.8
Imipenem	63.8	63.3	96.2	50.0	43.8	53.8	Levofloxacin	31.3	36.4
Levofloxacin	55.2	63.3	61.5	44.4	68.8	69.2	Linezolid	87.5	81.8
Nitrofurantoin	22.4	0	100	0	0	30.8	Moxifloxacin	37.5	45.5
Trimeth/Sulfa	39.7	6.7	53.8	27.8	43.8	66.7	Mupiracin	65.6	18.2
Ceftazidime	36.2	43.3	53.8	22.2	37.5	38.5	Nitrofurantoin	71.9	100
Ceftazidime/K	48.3	13.3	73.1	11.1	18.8	38.5	Oxacillin	31.3	0
Cefuroxime	32.8	0	53.8	0	37.5	15.4	Pencillin	3.1	72.7
Colistin	79.3	83.3	96.2	72.0	6.3	76.9	Rifampin	84.4	18.2
Ertapenem	53.4	3.3%	92.3	0	75.0	53.8	Synercid	87.5	18.2
Meropenem	60.3	60	92.3	44.4	68.8	69.2	Teicoplanin	90.6	90.9
Moxifloxacin	37.9	16.7	61.5	38.9	31.3	46	Tetracyclin	59.4	18.2
Norfloxacin	48.3	63.3	53.8	83.9	62.5	69.2	Trimeth/Sulfa	75.0	45.5
Pip/Tazo	53.4	70	76.9	44.4	43.8	53.8	Vancomycin	68.8	90.9
Tigecycline	94.8	26.7	100	83.3	31.3	69.2			
Tobramycin	60.3	93.3	80.8	61.1	62.5	69.2			

Gram-ve: Gram negative. Gram+ve: Gram positive. Amox/k: Amoxicillin/clavulanic acid. Cefotaxime/K C: Cefotaxime/ clavulanic acid. Ceftazidime/k: Ceftazidime/clavulanic. E. coli: Escherichia coli. K. pneumonia: Klebsiella pneumonia. Staph. aureus: Staphylococcus aureus. Strept. agalactica; Streptococcus agalactica.

Sensitivity of Gram negative organisms in OPD sector

E. coli and *K. pneumoniae* were constituted more than 30 isolates of Gram negative cultures. Sensitivity of Carbepenem antibiotics (Impinenem, Meropenem) >90%, pencillin and beta-lactamase inhibitors (amox/k >75%, pip/tazo>85%) and aminoglycosides >90% (Amikacin, Gentamicin & Tobramycin) were detected by the Gram negative isolates **(Table 5)**.

Penicillin and most B-lactam antibiotics except Impinenem and Meropenem were considered resistant in the isolated enterobacter species and *P. aerouginosa*. For sensitivity in *P. aerouginsa* and Enterobacter species; Carbepenem antibiotics (Impinenem, Meropenam) were 100%, Aminoglycosides (Amikacin 100%, Gentamicin >70%, Tobramycin >90%) and pip/tazo was ≥75% **(Table 5)**.

Quinolones including ciprofloxacin were sensitive >80%, while Moxifloxacin was >60% sensitive in *E. coli*, *K. pneumoniae* and Enterobacter species. Levofloxacin was sensitive ≥70% in the four isolated Gram negative species **(Table 5)**.

Sensitivity of Gram positive organisms in OPD sector

Penicillin and B-lactam antibiotics group played the most sensitive antibiotics in the isolated *Strept. agalactica*. MRSA and VRSA were less detected than in Inpatient/ICU sector. No VRE was detected in OPD group. Amox/K by >90% was sensitive in *Strept. agalactica* and *Enterococcus fecalis* while Trimrth/sulfa by >75% was sensitive in all 3 isolated Gram positive organisms **(Table 5).**

Sensitivity of Daptomycin/Teicoplanin, linezolid and vancomycin were > 85%, >60%, >75% respectively in the isolated Gram positive organisms **(Table 5)**.

Table 5: Antibiotic sensitivity in OPD sector

Antibiotic for Gram negative	***E. coli***	***K. pneumonia***	**Enterobacter species**	***Pseudomonas aeruginosa***	**Antibiotic for Gram positive**	***Strept. agalactica***	***Staph. aureus***	***Enterococcus fecalis***
Number of Gram-ve isolates (199)	N=125	N=44	N=13	N=10	**Number of Gram +ve isolates (141)**	N=64	N=46	N=25
	Antibiotic sensitivity %							
Amikacin	99.2	100	100	100	Amox/K	96.9	43.5	96.0
Amox/K	76.8	81.8	16.7	0	Ampicillin	75.0	8.7	64.0
Ampicillin	28.0	9.1	8.3	0	Azithromycin	60.9	47.8	28.0
Amp/Sulbactam	48.0	70.5	33.3	0	Cefoxitin	92.2	43.5	4.0
Aztreonam	47.2	70.5	58.3	80.0	Ciprofloxacin	53.1	37.0	52.0
Cefazolin	40.0	68.2	8.3	0	Clindamycin	64.1	47.8	12.0
Cefepime	60.8	77.3	58.3	80.0	Daptomycin	85.9	89.1	88.0
Cefotaxime	50.4	68.2	50	20.0	Erythromycin	53.1	47.8	28.0
Cefotaxime/K C	82.4	88.6	66.7	40.0	Fosfomycin	84.4	76.1	72.0
Cefoxitin	79.2	81.8	16.7	10.0	Fusidic acid	17.2	28.3	52.0
Ciprofloxacin	80.8	97.7	83.3	60.0	Gentamicin	26.6	84.8	28.0
Gentamicin	96.0	100	91.7	70.0	Imipenem	98.4	45.7	92.0
Imipenem	94.4	97.7	66.7	100.0	Levofloxacin	70.3	43.5	56.0
Levofloxacin	79.2	97.7	100	70.0	Linezolid	92.2	89.1	62.0
Nitrofurantoin	92.0	34.1	16.7	10.0	Moxifloxacin	76.6	43.5	48.0
Trimeth/Sulfa	56.8	75.0	100	0	Mupiracin	87.5	71.7	12.0
Ceftazidime	48.8	75.0	50.0	50.0	Nitrofurantoin	90.6	80.4	88.0
Ceftazidime/K	78.4	93.2	33.3	20.0	Oxacillin	87.5	43.5	8.0
Cefuroxime	48.0	63.6	25.0	20.0	Pencillin	79.7	4.3	56.0
Colistin	89.6	93.2	66.7	90.0	Rifampin	84.4	87.0	32.0
Ertapenem	93.6	97.7	91.7	30.0	Synercid	82.8	84.8	8.0
Meropenem	97.6	100	100	100.0	Teicoplanin	87.5	93.5	100
Moxifloxacin	61.6	81.8	75	30.0	Tetracyclin	34.4	65.2	24.0
Norfloxacin	76.8	95.5	91.7	80.0	Trimeth/Sulfa	82.8	80.4	76.0
Pip/Tazo	89.6	95.5	75.0	90.0	Vancomycin	93.8	78.3	100
Tigecycline	99.2	97.7	83.3	50.0				
Tobramycin	92.8	93.2	91.7	100.0				

Gram-ve; Gram negative. Gram+ve: Gram positive. Amox/k: Amoxicillin/clavulanic acid. Cefotaxime/K C: Cefotaxime/clavulanic acid. Ceftazidime/k: Ceftazidime/clavulanic. *E. coli*: *Escherichia coli*. *K. pneumonia*: *Klebsiella pneumonia*. *Staph. aureus*: *Staphylococcus aureus*

Specimen Categorization

The samples included in the antibiogram were categorized to urine, vaginal, respiratory (sputum, throat and tongue swab), skin related (wound, pus, umbilical swab, episiotomy swab, caesarian section swab & abscess), instrumental related (urinary catheters, central venous lines, endotracheal tube, Ryle tube, nasogastric tube, tracheostomy). Body fluid cultures included one CSF sample and one ascetic fluid culture. Vaginal and urine cultures were the most frequently investigated. Vaginal cultures were prominent in the OPD group while the other studied cultures were evident in ICU/patient group with statistical significance difference $p < 0.001$ **(Table 6)**.

Gram negative bacteria were isolated more frequently in Respiratory, urinary, skin, and instrumental related infections with statistical significance $p< 0.001$. In OPD group, Gram positive organisms were evident in vaginal cultures while Gram negative was eminent in urinary and vaginal cultures. In Inpatient/ICU group, Gram negative organisms were the prominent of cultures` results **(Table 7)**.

Antibiotic Sensitivity according to specimen type

Antibiotic Sensitivity of Gram positive organisms

Vaginal cultures` organisms were the most registered sensitive ones in the investigated cultures. Amox/K was sensitive oral antibiotic by >80% & > 60% for vaginal/urinary and instrumental cultures accordingly **(Table 8)**.

Trimeth/Sulfa was sensitive oral antibiotic by >60% in all isolates except in instrumental related cultures. Tecoplanin and Lizolid by >80%, Daptomycin, Nitrofurontin and vancomycin by >60% were sensitive antibiotics in the detected Gram positive organisms` samples. Respiratory and instrumental related infections were largerly not sensitive to Imipenem **(Table 8)**.

Antibiotic Sensitivity of Gram negative organisms

In respiratory, skin and instrumental related cultures; Pencillin, B-lactams, Quinolones were mostly resistant while Aminoglycosides (Gentamicin, Tobramycin) were sensitive by >60% except for Tobramycin in instrumental related infections was mostly resistant. Amikacin by >70%, Colistin and Tigecyclin by > 60% were broad sensitive in the investigated cultures **(Table 9)**.

Amox/K, Ciprofloxacin and Moxifloxacin by > 60% and Levofloxacin by >70% were sensitive oral antibiotics in Vaginal and urinary cultures **(Table 9)**.

Table 6: Specimen categorization

Specimen type	Total N=561 N (%)	Inpatient/ICU N=221 N (%)	OPD N=340 N (%)	p-value*
Vaginal	228 (51.3)	11 (5.0)	217 (63.8)	<0.001
Urinary	166 (29.59)	69 (31.2)	97 (28.5)	
Respiratory	91 (16.22)	81 (36.7)	10 (2.9)	
Instrumental	25 (4.46)	25 (11.3)	0 (0)	
Skin related	49 (8.7)	33 (14.9)	16 (4.7)	
Body fluid	2 (0.35)	2 (0.9)	0 (0)	

**p-value ≤ 0.05 is statistically significant.*

Table 7: Types of infection according to sample and patient location

Specimen type	All patients		p-value*	Inpatient/ICU		p-value*	OPD		p-value*
	Gram-ve	Gram+ve		Gram-ve	Gram+ve		Gram-ve	Gram+ve	
	N (%)	N (%)		N (%)	N (%)		N (%)	N (%)	
Vaginal	116(50.9)	112(49.1)	<0.001	8 (72.7)	3 (27.3)	0.133	108(49.8)	109(50.2)	<0.001
Urinary	133(80.1)	33 (19.9)		57(82.6)	12(17.4)		76 (78.4)	21 (21.6)	
Respiratory	60 (65.9)	31 (34.1)		54(66.7)	27(33.3)		6 (60)	4 (40)	
Instrumental	22 (88.0)	3 (12.0)		22(88.0)	3 (12.0)		0 (0)	0 (0)	
Skin related	35 (71.4)	14 (28.6)		26(78.8)	7 (21.2)		9 (56.3)	7 (43.8)	

**p-value ≤ 0.05 is statistically significant. Gram-ve: Gram negative. Gram+ve: Gram positive.*

Table 8: Antibiotic Sensitivity of Gram positive organisms according to specimen type

Sepcimen type/ Antibiotic	Respiratory	Vaginal	Urinary	Skin	Instrumental
	Antibiotic Sensitivity %				
Amox/K	45.2	83.9	63.6	57.1	66.7
Ampicillin	19.4	55.4	48.5	21.4	33.3
Azithromycin	32.3	52.7	51.5	50.0	33.3
Cefoxitin	48.4	64.3	45.5	42.9	33.3
Ciprofloxacin	35.5	50.9	42.4	50.0	33.3
Clindamycin	58.1	50.0	48.5	64.3	33.3
Daptomycin	77.4	85.7	87.9	92.9	66.7
Erythromycin	38.7	45.5	63.6	50.0	33.3
Fosfomycin	61.3	78.6	75.8	85.7	33.3
Fusidic acid	32.3	27.7	24.2	28.6	0.0
Gentamicin	64.5	42.9	39.4	78.6	66.7
Imipenem	54.8	85.7	60.6	64.3	33.3
Levofloxacin	32.3	64.3	42.4	57.1	33.3
Linezolid	83.9	88.4	81.8	78.6	100.0
Moxifloxacin	41.9	64.3	48.5	50.0	33.3
Mupiracin	71.0	65.2	69.7	71.4	33.3
Nitrofurantoin	80.6	85.7	90.9	85.7	66.7
Oxacillin	29.0	60.7	45.5	35.7	33.3
Pencillin	16.1	55.4	48.5	14.3	33.3
Rifampin	90.3	73.2	69.7	78.6	66.7
Synercid	90.3	67.9	69.7	71.4	66.7
Teicoplanin	96.8	91.1	87.9	85.7	100.0
Tetracyclin	61.3	39.3	42.4	71.4	33.3
Trimeth/Sulfa	74.2	80.4	66.7	78.6	33.3
Vancomycin	74.2	92.0	90.9	64.3	100.0

Amox/k: Amoxicillin/clavulanic acid. Cefotaxime/K C: Cefotaxime/clavulanic acid. Ceftazidime/K: Ceftazidime/clavulanic.

Table 9: Antibiotic Sensitivity of Gram negative organisms according to specimen type

Speciemen/Antiboitic	Respiratory	Vaginal	Urine	Skin	Instrumental
	Antiboitic sensitivity%				
AMIKACIN	76.7	99.1	94.0	91.4	77.3
Amox/K	25.0	73.3	61.7	28.6	18.2
Ampicillin	3.3	18.1	28.6	5.7	0.0
Amp/Sulbactam	31.7	51.7	51.9	25.7	4.5
Aztreonam	35.0	57.8	45.1	22.9	31.8
Cefazolin	20.0	46.6	40.6	14.3	9.1
Cefepime	53.3	70.7	57.9	42.9	31.8
Cefotaxime	30.0	56.0	47.4	28.6	9.1
Cefotaxime/K	31.7	80.2	76.7	40.0	27.3
Cefoxitin	26.7	74.1	68.4	37.1	22.7
Ciprofloxacin	55.0	88.8	69.2	68.6	50.0
Gentamicin	65.0	96.6	85.7	80.0	63.6
Imipenem	56.7	94.0	88.7	60.0	50.0
Levofloxacin	53.3	90.5	72.9	60.0	59.1
Nitrofurantoin	8.3	62.1	68.4	20.0	22.7
Trimeth/Sulfa	31.7	65.5	54.1	37.1	22.7
Ceftazidime	40.0	60.3	50.4	34.3	18.2
Ceftazidime/K	33.3	77.6	65.4	34.3	27.3
Cefuroxime	23.3	51.7	44.4	20.0	4.5
Colistin	75.0	86.2	85.0	65.7	63.6
Ertapenem	31.7	91.4	82.0	48.6	36.4
Meropenem	51.7	99.1	91.0	71.4	54.5
Moxifloxacin	35.0	65.5	60.2	42.9	22.7
Norfloxacin	50.0	87.1	68.4	57.1	50.0
Pip/Tazo	56.7	89.7	82.0	57.1	45.5
Tigecycline	76.7	94.8	91.7	62.9	72.7
Tobramycin	70.0	93.1	84.2	85.7	54.5

Amox/k: Amoxicillin/clavulanic acid. Cefotaxime/K C: Cefotaxime/ clavulanic acid. Ceftazidime/k: Ceftazidime/ clavulanic.

DISCUSSION

The global action plan to fight antimicrobial resistance (AMR) adopted by the WHO sets several objectives and recommendations to enhance antibiotic surveillance and research, to strengthen knowledge and improve the awareness regarding AMR, to optimize the use of antimicrobial agents, and to decrease the rate of infections[16]. Our study is in line with these recommendations. This research presents an analysis of the antibiotic sensitivity patterns of Gram-negative and Gram-positive organisms isolated from various clinical specimens across different sectors, including Inpatient/ICU and Outpatient (OPD). These results help to understand the distribution of bacterial resistance and the effectiveness of antimicrobial agents across specimen types. The Gram-negative organisms, including *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Escherichia coli* were prevalent in the Inpatient/ICU sector as well as Outpatient sector. This is in line with published evidence[17,18]. However, higher prevalence was reported in the Inpatient/ICU compared to the Outpatient group. This higher prevalence, is mainly due to the increased use of invasive devices, immunocompromised patients, and increased widespread antibiotic and detergents use in the hospital environment[19].

A notable finding in the Inpatient/ICU group was the prevalence of multidrug-resistant organisms (MDROs). These pathogens pose a significant challenge to treatment, as they are resistant to multiple classes of antibiotics, limiting therapeutic option. The presence of significant resistance in *E.coli*, *K. pneumoniae* and *Pseudomonas aeruginosa* to certain beta-lactams (e.g. Cefuroxime, Ampicillin), suggests the presence of significant resistance mechanisms like beta-lactamase production. This is in accordance with the results of Dodoo et al.[20], who showed high resistance to beta-lactam antibiotics. Despite these findings, certain antibiotics still demonstrate effectiveness against these organisms. The most effective antibiotics across these species were Amikacin, Gentamicin, Imipenem, Meropenem, and Colistin. This is similar to another study in Saudi Arabia which shows high susceptibility rate to amikacin in Pseudomonas infection[21]. For Gram-positive organisms, similar patterns were observed, with *Staphylococcus aureus* (particularly **methicillin-**

resistant *Staphylococcus aureus* [MRSA]) and *Enterococcus faecalis* showing high sensitivity to *Daptomycin,* Vancomycin*, Linezolid,* and *Teicoplanin*. This is in accordance with other studies in Saudi Arabia that have documented escalating rates of antibiotic resistance and MDRO[22-24]**.** So, there is a need for periodical evaluation of the magnitude and risk factors of MDROs to adapt an appropriate prevention and control strategy.

The antibiotic sensitivity testing results highlight significant variability in antibiotic effectiveness across different specimen types. Respiratory and urinary specimens generally demonstrated better antibiotic sensitivity than skin and instrumental specimens. Meropenem and Tigecycline exhibited consistently high sensitivity across all specimen types, suggesting their broad-spectrum efficacy against Gram-negative organisms. Likewise, Amikacin, Gentamicin, and Imipenem showed strong sensitivity in most specimen types, with particularly high efficacy in respiratory, vaginal, and urinary samples.

In contrast, Ampicillin, Amoxicillin/Clavulanic acid (Amox/K), and Ampicillin/Sulbactam exhibited notably lower sensitivity across most specimen types. Ampicillin, in particular, was ineffective against respiratory, skin, and instrumental specimens. This may be linked to the rising incidence of respiratory infections caused by *Haemophilus influenzae* and *Moraxella catarrhalis*, as the frequency of pneumococcal infections has decreased. The increased production of beta-lactamases in these strains could explain the observed resistance to amoxicillin[25]. This trend may be partly attributed to the success of pneumococcal vaccination programs, which have reduced *Streptococcus pneumoniae* infections, particularly in children and the elderly, as evidenced by the absence of *S. pneumoniae* in our study's adult and elderly populations.

Antibiotics such as Ciprofloxacin, Levofloxacin, and Piperacillin/Tazobactam demonstrated moderate to high sensitivity in various specimen types. However, there was a notable reduction in sensitivity in instrumental and skin samples, suggesting that resistance is more prevalent in these specimen types. These findings align with a previous study by Al-Tawfiq et al. (2020)[26], which reported low susceptibility of fluoroquinolones in Gram-negative bacteria, further supporting the concern of emerging resistance in specific clinical settings. The resistance to fluoroquinolones is multifactorial and is the result of one or more mechanisms such as: target-site gene mutations, increased production of efflux pumps, presence of modifying enzymes, or target-protection proteins[27].

Based on these findings, it is recommended that clinicians consider specimen-specific sensitivities when selecting antibiotics for the treatment of Gram-negative infections. **Meropenem, Tigecycline, Imipenem**, and **Amikacin** should be prioritized for their broad spectrum of activity, particularly in difficult-to-treat specimen types such as skin and instrumental infections. For urinary and vaginal infections, antibiotics like **Amikacin, Gentamicin**, and **Levofloxacin** remain highly effective. However, careful attention should be given to the increasing resistance in antibiotics like **Ampicillin** and **Amox/K,** which should be avoided in favor of more potent alternatives.

The study also highlights the significant presence of Acinetobacter species in elderly patients, which is a cause for concern due to the notorious resistance profile of this pathogen. Acinetobacter species, particularly in hospital settings, are frequently associated with severe infections, including pneumonia, bloodstream infections, and wound infections, especially in critically ill or immunocompromised individuals[28]. The increased occurrence in older adults further underscores the need for heightened vigilance in managing infections in this age group, including the use of appropriate infection control measures to prevent outbreaks of this multidrug-resistant organism.

CONCLUSION

This report highlights significant resistance patterns among both **Gram-negative** and **Gram-positive** pathogens in the impatient/ICU and OPD sectors of our hospital. Resistance patterns revealed a trend of some antibiotics on the WHO Watch and Reserve loosing efficacy. So, effective treatment can be ensured mainly by adhering to the recommendations based on antibiotic sensitivity data. Also, it is crucial to promote **antimicrobial stewardship programs** that should focus on both the proper selection of initial empirical therapy and timely de-escalation based on culture and sensitivity results. Surveillance and monitoring should be enhanced to detect early resistance trends, especially in high-risk areas such as the ICU, where prolonged antibiotic use often leads to resistance development. Foster a culture of careful antibiotic use will protect both patient outcomes and public health.

Recommendations

This study has several limitations that should be considered when interpreting the findings. The research was conducted at a single healthcare institution, which limits the generalizability of the results to other regions or healthcare settings. Although the sample size was large, it may not fully represent all patient populations, particularly in specific Outpatient settings. Importantly, factors such as patient comorbidities, prior antibiotic use, and hospital-acquired infections were not analyzed, and these could significantly affect resistance patterns. The study also did not explore the molecular mechanisms of resistance, which would provide deeper insights into the genetic factors involved. Additionally,

clinical outcomes of infections caused by resistant organisms were not assessed, leaving a gap in understanding how resistance impacts patient management and recovery. Addressing these limitations in future multi-center studies, including molecular profiling and clinical outcome evaluations, would enhance our understanding of antimicrobial resistance and improve treatment strategies.

Declarations:

Funding: This project was funded through the reactivation and rebuilding of existing lab initiative project from the Research Development and Innovation Authority (RDIA), Saudi Arabia (grant number ibnsina-2023-R-2-1-HW-2007).

Transparency declarations: None to declare.

Acknowledgement: The authors would like to express their gratitude to the Research Development and Innovation Authority (RDIA) for supporting this research. They would also like to express their gratitude to all health care workers in Ibn Sina College Hospital for their great cooperation and support.

Author Contributions:

All authors contributed equally to the conception, design, writing, and editing of this review. All authors have read and approved the final manuscript.

Availability of data and material: The datasets used and analyzed during this study are available from the corresponding author on reasonable request.

Competing interests: No conflict of interests.

REFERENCES

1. El-Khawaga AM, Elmaghraby K, Orlandini M. Amoxicillin conjugated functionalized zinc ferrite nanoparticles for enhanced antibacterial, antibiofilm, and antioxidant activities. Scientific Reports 2025, 15 (1), 24951.
2. Verma T, Aggarwal A, Singh S, Sharma S, Sarma SJ. Current challenges and advancements towards discovery and resistance of antibiotics. Journal of Molecular Structure 2022, 1248, 131380.
3. Salam MA, Al-Amin MY, Salam MT, Pawar JS, Akhter N, Rabaan AA, Alqumber MAA. Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. 2023, 11 (13), 1946.
4. Manga MM, Mohammed Y, Suleiman S, Fowotade A, Yunusa-Kaltungo Z, Usman MA, Abulfathi AA, Saddiq M I. Antibiotic prescribing habits among primary healthcare workers in Northern Nigeria: a concern for patient safety in the era of global antimicrobial resistance. PAMJ-One Health 2021, 5.
5. El-Khawaga AM, Orlandini M, Raucci L, Elmaghraby K. Magnetic nanoparticles as a promising antimicrobial agent for combating multidrug resistant bacteria: a review. Discover Applied Sciences 2025, 7 (7), 652.
6. Naghavi M, Vollset SE, Ikuta KS, Swetschinski LR, Gray AP, Wool EE, Aguilar GR, Mestrovic T, Smith G, Han C. Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050The Lancet 2024, 404 (10459), 1199.
7. Alshehri AA, Aldali JA, Abdelhamid MA, Alanazi AA, Alhuraiz, RB, Alanazi, LZ, Alshmrani, MA, Alqahtani, AM, Alrshoud, MI, Alharbi, RF. Implementation of Antimicrobial Stewardship Programs in Saudi Arabia: A Systematic Review. 2025, 13 (2), 440.
8. https://www.who.int/publications/m/item/kingdom-of-saudi-arabia--second-antimicrobial-resistance-action-plan-2022-2025.
9. Pakyz AL. The utility of hospital antibiograms as tools for guiding empiric therapy and tracking resistance: insights from the Society of Infectious Diseases Pharmacists. Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy 2007, 27 (9), 1306.
10. Wayne PA. Clinical and laboratory standards institute. Performance standards for antimicrobial susceptibility testing. 2011.
11. Jorgensen S, Zurayk M, Yeung S, Terry J, Dunn M, Nieberg P, Wong-Beringer A. Emergency department urinary antibiograms differ by specific patient group. Journal of clinical microbiology 2017, 55 (9), 2629.
12. Grodin L, Conigliaro A, Lee S-Y, Rose M, Sinert R. Comparison of UTI antibiograms stratified by ED patient disposition. The American Journal of Emergency Medicine 2017, 35 (9), 1269.
13. Alharbi AS. Bacteriological profile of wound swab and their antibiogram pattern in a tertiary care hospital, Saudi Arabia. Saudi Medical Journal 2022, 43 (12), 1373.
14. Weinstein MP, Lewis JS. The clinical and laboratory standards institute subcommittee on antimicrobial susceptibility testing: background, organization, functions, and processes. Journal of clinical microbiology 2020, 58 (3), 10.
15. Marin C, Lorenzo-Rebenaque L, Laso O, Villora-Gonzalez J, Vega S. Pet reptiles: a potential source of transmission of multidrug-resistant Salmonella. Frontiers in Veterinary Science 2021, 7, 613718.
16. World Health O. Comprehensive Review of the WHO Global Action Plan on Antimicrobial

Resistance—Volume 1: Report. WHO Evaluation Office: Geneva, Switzerland 2021.

17. Fahim NAE. Prevalence and antimicrobial susceptibility profile of multidrug-resistant bacteria among intensive care units patients at Ain Shams University Hospitals in Egypt—a retrospective study. Journal of the Egyptian Public Health Association 2021, 96 (1), 7.
18. Ruppé É, Woerther P-L, Barbier F. Mechanisms of antimicrobial resistance in Gram-negative bacilli. Annals of intensive care 2015, 5 (1), 21.
19. Negm EM, Elgharabawy ES, Badran SG, Raafat AON, Soliman ST, Mahmoud HM, Tawfik AE, Hawary ATEL, El Hawary A, Elhewala A. Analysis of cumulative antibiogram reports in intensive care units at an Egyptian University Hospital. Journal of Infection and Public Health 2023, 16 (8), 1220.
20. Dodoo CC, Odoi H, Mensah A, Asafo-Adjei K, Ampomah R, Obeng L, Jato J, Hutton-Nyameaye, A, Aku, T. A, Somuah, S. O. Development of a local antibiogram for a teaching hospital in Ghana. JAC-antimicrobial resistance 2023, 5 (2), dlad024.
21. Thabit AK, Alghamdi AM, Miaji MY, Alharbi FS, Jawah AF, Alturki F, Hosin N, Bazuqamah M, Almutairi MS, Alhamed H. Antibiotic susceptibility of Pseudomonas aeruginosa in Saudi Arabia: a national antimicrobial resistance surveillance study. Frontiers in Public Health 2024, 12, 1436648.
22. Alenazi FS, Alzahrani KMS, Alhuwaiti MM, Alshahri AA. Antibiotic resistance in Saudi Arabia; review. International Journal of Medicine in Developing Countries 2022, 6 (2), 399.
23. Almaghrabi MK, Joseph MRP, Assiry MM, Hamid ME. Multidrug-Resistant Acinetobacter baumannii: An Emerging Health Threat in Aseer Region, Kingdom of Saudi Arabia. Canadian Journal of Infectious Diseases and Medical Microbiology 2018, 2018 (1), 9182747.
24. Saeedi FA, Hegazi MA, Alsaedi H, Alganmi AH, Mokhtar JA, Metwalli EM, Hamadallah, H, Siam, G. S, Alaqla, A, Alsharabi, A. Multidrug-resistant bacterial infections in pediatric patients hospitalized at King Abdulaziz University Hospital, Jeddah, western Saudi Arabia. Children 2024, 11 (4), 444.
25. World Health O. The WHO AWaRe (access, watch, reserve) antibiotic book; World Health Organization, 2022.
26. Al-Tawfiq JA, Rabaan AA, Saunar JV, Bazzi AM. Antimicrobial resistance of gram-negative bacteria: A six-year longitudinal study in a hospital in Saudi Arabia. Journal of Infection and Public Health 2020, 13 (5), 737.
27. Redgrave LS, Sutton SB, Webber MA, Piddock LJV. Fluoroquinolone resistance: mechanisms, impact on bacteria, and role in evolutionary success. Trends in Microbiology 2014, 22 (8), 438.
28. Almasaudi SB. Acinetobacter spp. as nosocomial pathogens: Epidemiology and resistance features. Saudi Journal of Biological Sciences 2018, 25 (3), 586.