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Antimicrobial Susceptibility of Gram-Negative Infections in King Faisal Medical Complex at Taif, Saudi Arabia

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Abstract

Objectives: Describe susceptibility patterns to several antimicrobials in Gram-negative pathogens isolated from patients in King Faisal Medical Complex (KFMC) at Taif, Saudi Arabia over a 6-month period.

Methods: The study included a cumulative antibiogram of Gram-negative bacteria (GNB). Interpretation of the antimicrobial susceptibility tests was based on the Clinical and Laboratory Standards Institute (CLSI) guidelines and the Phoenix system.

Results: Overall, 763 clinical infections by GNB isolates of the specimens collected during six months were culture-positive. Among the array of GNB, *Escherichia coli* numbered 290 (38.0%) was the most frequently identified, then *Klebsiella pneumoniae* 276 (36.2%), *Pseudomonas aeruginosa* 77 (10.1%), *Acinetobacter baumannii* 48 (6.3%), *Proteus* spp. 31 (4.1%), *Citrobacter koseri* 11 (1.4%), *Serratia* spp. 8 (1.0 %), *Enterobacter aerogenes* 7 (0.9%), *Klebsiella Oxytoca* 4 (0.5%), *Providencia rettgeri* 3 (0.4 %), *Klebsiella ozaenae* 3 (0.4%), *Morganella morganii* 2 (0.3%), *Stenotrophomonas maltophilia* 2 (0.3 %), and *Pseudomonas puda* 1 (0.1%). Fifty-one isolates were resistant to all tested antibiotics, but 97 (12.7 %) were susceptible to all the tested antibiotics. The majority (87.3%) of isolates were resistant to one or more antimicrobials tested. In general, 83% of the bacterial species were MDR. The carbapenem sensitivity was 68.7% for all GNB isolates, 47.3% and 52.3% of *K. pneumoniae*, 20.8% and 25% of *Acinetobacter*, and 64.1% and 75.6% of *P. aeruginosa* to imipenem and meropenem, respectively. The carbapenem sensitivity for *E. coli* was extremely high showing 100% and 99.9% for imipenem and meropenem, respectively. Antibiotic sensitivity of the most isolated GNB pathogens was highly variable showing that tigecycline is the most effective antibiotic with 82.4% sensitivity while was non-effective for *Acinetobacter*. The colistin sensitivity was 88.3% for *E. coli*, 69.2% for *P. aeruginosa*, 45.5% for *K. pneumoniae* and less effective against *A. baumannii*.

Conclusion: Antibiotic resistance among *K. pneumoniae*, *A. baumannii* and *P. aeruginosa* was high for many used antibiotics, thus continued surveillance is needed.

Keywords: Antimicrobial pattern; susceptibility; multi-drug resistance; antibiotic

Introduction

Antimicrobial resistance (AMR) is a major threat to public health forcing significant health loads and economic burdens on healthcare system and patients.[1] Unless proactive solutions are found to handle AMR, global costs are estimated to reach 3 trillion USD yearly by 2050 and in addition, 10 million people could die annually; cumulated costs could reach over 100 trillion USD.[2] Multiple studies addressing increased resistance rates among bacterial organisms in the Middle East with considerable variation in the resistance pattern in the region, multiple drivers were cited as contributing to the increased resistance rates.[3] The main drivers of AMR include the overuse and misuse of antibiotics, poor infection and disease prevention and control in health-care settings, lack of awareness and knowledge, lack of access to clean water, sanitation and hygiene, and poor access to quality affordable medicines and diagnostics.[4] The main AMR organisms are defined as those mentioned by WHO as "priority pathogens" for public health significance. There are 8 pathogens: *Escherichia coli*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Salmonella* spp., *Shigella* spp., *Streptococcus pneumoniae*, *Staphylococcus aureus*, and *Neisseria gonorrhoeae*. Antibiotics and antimicrobial combinations to bacterial pathogens under Global Antimicrobial Resistance and Use Surveillance System surveillance include penicillins, third- and fourth-generation cephalosporins, carbapenems, aminoglycosides, fluoroquinolones, tetracyclines, macrolides, polymyxins, and co-trimoxazole.[5]

Routine clinical microbiological laboratory data provide profiles of the sensitivities to antimicrobial agents of specific bacteria for monitoring, responding and controlling emerging antimicrobial issues, and this data can be utilized to assist in the selection of empirical treatment by selecting the most appropriate antimicrobial agents before susceptibility results are available but remains generally unexploited for purposes of epidemiological surveillance.[6] One of the known tools for monitoring resistance is an antibiogram that showed the development of antibiotic resistance and susceptibility data. The evaluation of an antibiogram over time allows the development of cumulative proportions of bacterial pathogens that are sensitive to specific antimicrobial agents and this activity further enhances the selection of empiric antibiotics. Study aimed to examine patterns of antimicrobial susceptibility of some gram-negative pathogens isolated from inpatients and outpatients using the surveillance data datasets collected from King Faisal Medical Complex (KFMC) over a six months period (November 2021 to April 2022), in Taif, Saudi Arabia.

Methods

Study Design

In this study, we evaluated the antibiogram of GNB at KFMC in Taif, Saudi Arabia over six months (November 2021 to April 2022) which is one of the biggest hospitals in the western region. The bed capacity of the hospital is 800 beds distributed over different sections; 27 beds of ICU, 13 beds of CCU (cardiac care unit), 13 beds of HDU-BED (high dependent unit), 10 beds of burn units, 54 beds of MMW (male medical ward), 54 beds of FMW (female medical ward), 80 beds of MSW (male surgical ward), 80 beds of FSW (female surgical ward), 54 beds of ISO (isolation), 27 beds of FMM (fetal and maternal medicine), 27 beds of inpatient medical ward, 61 beds distributed between ER (emergency), LTCU (long term care unit), NICU (nursery intensive care unit), INPS (infants & pediatrics isolation), ANT5 (antenatal care)and has major maternity wards (300 beds). Thus, the hospital provides primary, secondary, and tertiary care to eligible care recipients. The study was approved by the ethics committee review Board of Research and Studies Department of Directorate of Health Affairs in Taif in October 2021. The approval number 2023-B-2 of Committee Registration Number in KACST, Saudi Arabia: (H-02-T-123).

Antimicrobial Susceptibility Testing

The study is an *in-vitro* surveillance study of antibiotic susceptibility patterns among GNB isolates utilizing an antibiogram obtained from the laboratory department. The interpretation of the antibacterial susceptibility tests was based on the Clinical and Laboratory Standards Institute (CLSI) guidelines.[7] Antibacterial susceptibility tests and bacterial identification were done using an automated system (Phoenix™, Dade Behring Inc., Sacramento, CA, USA). To ensure data compatibility, quality control was performed using control strains from the following American Type Culture Collection (ATCCs): *Pseudomonas aeruginosa* ATCC 2853, *E. coli* ATCC25922, and *K. pneumoniae* ATCC 27736. Data are only included when the quality control test results were in acceptable ranges. The tested antimicrobials were ampicillin, amoxicillin/clavulanic acid, pipercillin/tazobactam, cefalotin, cefoxitin, ceftazidime, ceftriaxone, imipenem, meropenem, gentamicin, ciprofloxacin, tigecycline, nitrofurantoin, and azetronam.

Statistical Analysis

The rate of antibiotic resistance to clinical infectious organisms was calculated as the percentage of each GNB isolate divided by the total number of tested isolates. We also compared the pathogens frequency and the susceptibility pattern among every month utilizing a Chi square test using SPSS software (IBM Corp. released 2017, IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.), a significant P value was considered for ($P < 0.05$).

Results

A total of 13,501 clinical specimens were sent from different KFMC wards from various clinical samples (4,947 blood samples and 8,554 other samples including urine, sputum, swabs, body fluids & catheter) during the study period from November 2021 to April 2022.

Clinical Infection Types of GNB Organisms at KFMC Over 6 Months

Overall, 763 clinical infections by gram-negative isolates of the specimens collected were culture-positive (Table 1) and (Figure 1). Among the array of Gram-negative organisms, *E. coli* numbered 290 (38.0%) was the most frequently identified, then *K. pneumoniae* 276 (36.2%), *P. aeruginosa* 77 (10.1%), *A. baumannii* 48 (6.3%), *Proteus* spp.

Table 1. **Organism species count of clinical bacterial isolates collected from KFMC for six months during 2021–2022**

Organisms	Month 11	Month 12	Month 1	Month 2	Month 3	Month 4
1. *Escherichia coli*	56	53	61	62	23	35
2. *Klebsiella pneumoniae*	60	57	43	43	32	41
3. *Pseudomonas aeruginosa*	10	11	15	13	11	17
4. *Acinetobacter baumannii*	4	4	5	7	13	15
5. *Proteus* spp.	4	4	5	5	6	7
6. *Citrobacter koseri*	2	4	2	3	0	0
7. *Enterobacter aerogenes*	1	3	1	0	1	1
8. *Morganella morganii*	2	0	0	0	0	0
9. *Providencia rettgeri*	1	0	1	1	0	0
10. *Serratia* spp.	1	2	1	2	1	1
11. *Klebsiella Oxytoca*	2	0	0	0	1	1
12. *Pseudomonas puda*	0	0	0	0	1	
13. *Stenotrophomonas maltophilia*	0	0	0	0	1	1
14. *klebsiella ozaenae*	2	0	0	0	0	1
Total	145	138	134	136	90	120
P-value			0.018			

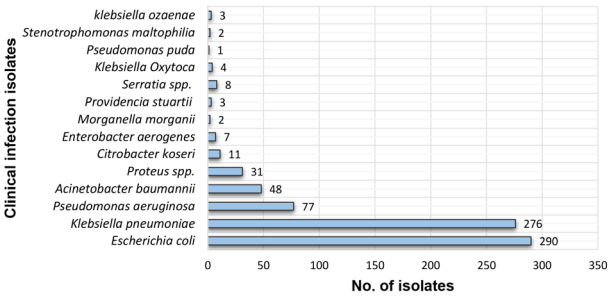

Fig. 1 **Diagram of organism species count of clinical bacterial isolates collected from KFMC for six months during 2021–2022.**

31 (4.1%), *Citrobacter koseri* 11 (1.4 %), *Serratia* spp. 8 (1.0 %), *Enterobacter aerogenes* 7 (0.9 %), *Klebsiella Oxytoca* 4 (0.5%), *Providencia rettgeri* 3 (0.4 %), *Klebsiella ozaenae* 3 (0.4 %), *Morganella morganii* 2 (0.3 %), *Stenotrophomonas maltophilia* 2 (0.3 %), and *Pseudomonas puda* 1 (0.1%) as shown at Table 1 and Figure 1. Statistical analysis showed that there is a highly significant difference between various months among study period and type of organisms using Chi square test ($P = 0.018$).

Antimicrobial Resistance Profiles of GNB Isolates

Generally, 51 (6.7 %) Gram-negative bacteria were resistant to alltested antibiotics. Resistance rates were recorded against ampicillin (81.7%), amoxicillin/clavulanic acid (61.3%), piperacillin/tazobactam (54%), cefalotin (58.2%), cefoxitin (57%), ceftazidime (54.7%), ceftriaxone (56.4%), cefepime (47.7%), ceftolozane/tazobactam (47.6%), imipenem (31.3%), meropenem (27.7%), amikacin (38.3%), gentamicin (40.7%), ciprofloxacin (52.5%), tigecycline (17.6%), nitrofurantoin (64.4%), trimethoprim/sulfamethoxazole (64%), azetronam (64.3%) and colistin (37.4%) (Table 2, Figure 2). Multi-drug resistance profiles of the total isolates, 97 (12.7%) were susceptible to all the tested antibiotics. The majority of isolates (87.3%) were resistant to one or more antimicrobials tested. In general, 634 (83%) of bacterial species were MDR. The carbapenem sensitivity was 68.7% for all Gram-negative isolates, 47.3% and 52.3% imipenem and meropenem sensitivity of *K. pneumoniae*, 20.8% imipenem and 25% meropenem sensitivity of *Acinetobacter*, and 64.1% imipenem and 75.6% meropenem sensitivity of *P. aeruginosa* while the carbapenem sensitivity for *E. coli* was extremely high, showing sensitivity percentages of 100% and 99.9% for imipenem and meropenem. Antibiotic sensitivity of the most isolated Gram-negative pathogens was highly variable showing that tigecycline is the most effective antibiotic with 82.4% sensitivity level while it was non-effective against *Acinetobacter E. coli* colistin sensitivity was 88.3% while it was 69.2% for *P. aeruginosa*, 45.5% for *K. pneumoniae* and it was less effective against *Acinetobacter*. Statistical analysis showed that there is a highly significant difference between every one of the six months during the study period and the number of resistances isolates to different antibiotics using Chi square test ($P < 0.000$).

E. coli

Isolates of *E. coli* exhibited 72.4% resistance to ampicillin, 54.1% to trimethoprim/sulfamethoxazole, 46.2% to nitrofurantoin, 44.8% to amoxicillin/clavulanic acid, 37.2% to cefalotin, 36.6% to cefoxitin, 35.2% to ceftriaxone, 34.1% to ceftazidime, 33.4% to azetronam, 31.7% to piperacillin/tazobactam, 26.6% to ciprofloxacin, 25.2% to cefepime, 25.2% to ceftolozane/tazobactam, 17.6% to amikacin, 15.9% to gentamicin, 11.7% to colistin, 3.4% to tigecycline, 1.0% to meropenem and 0.0% to imipenem (Table 3).

Klebsiella spp

Klebsiella spp. isolates showed 89.0% resistance to ampicillin, 80.6% to nitrofurantoin, 75.3% to trimethoprim/sulfamethoxazole, 73.9% to ciprofloxacin, 73.5% to piperacillin/tazobactam, 73.1% to amoxicillin/clavulanic acid, 71.4% to cefalotin, 70.7% to cefoxitin, 70.0% to ceftazidime, 70.0% to ceftriaxone, 66.4% to cefepime, 65.4% to ceftolozane/tazobactam, 62.7% to azetronam, 59.0% to amikacin, 58.7% to gentamicin, 54.5% to colistin, 52.7% to imipenem, 47.7% to meropenem, and 15.5% to tigecycline (Table 3).

A. baumannii

A. baumannii isolates showed 100% resistance to ampicillin, 100% to tigecycline, 97.90% to azetronam, 97.90% to colistin, 97.90% to cefalotin, 97.90% to cefoxitin, 97.90% to ceftazidime, 97.90% to ceftriaxone, 94.70% to gentamicin, 91.70% to amoxicillin/clavulanic acid, 91.70% to nitrofurantoin, 89.60% to piperacillin/tazobactam, 89.60% to trimethoprim/sulfamethoxazole, 87.50% to cefepime, 87.50% to ceftolozane/tazobactam, 83.30% to amikacin, 79.20% to imipenem, 75% to meropenem, and 12.50% to ciprofloxacin (Table 4).

Pseudomonas spp.

Pseudomonas spp. isolates showed 85.9% resistance to ampicillin, 76.9% to amoxicillin/clavulanic acid, 75.6% to nitrofurantoin, 66.7% to cefalotin, 64.1% to trimethoprim/sulfamethoxazole, 62.8% to cefoxitin, 60.3% to ceftriaxone, 53.8% to ceftazidime, 52.6% to piperacillin/tazobactam, 51.3% to ciprofloxacin, 47.4% to azetronam, 46.2% to cefepime, 46.2% to ceftolozane/tazobactam, 41% to gentamicin, 38.5% to tigecycline, 35.9% to imipenem, 33.3% to amikacin, 30.8% to colistin, and 24.4% to meropenem (Table 4).

Discussion

In Saudi Arabia, misuse of antibiotics is complicated and high primarily because antibiotics were available to buy over the counter by anyone via the community pharmacies without a legal prescription. Only four years ago, the Saudi Ministry of Health implemented a nationwide ban on the sale of antibiotics without a legal prescription; however, despite this law, dispensing antibiotics without a prescription is still common.[8]

In a previous national study, Gramnegative pathogens were 2.3times more likely to cause hospital acquired infections compared to grampositive bacteria (71.9% vs. 28.1%) at three private tertiary care hospitals over a 5years period (Alhumaid et al., 2021) similar with many Saudi studies made in different cities in Saudi Arabia including Riyadh (Balkhy et al., 2020; El-Saed et al., 2020), Jeddah (Alshammari et al., 2022), Makkah (Haseeb et al., 2016), and Aljouf (Bandy and Almaeen, 2020).[9-13]

Table 2. **Antibiotics resistance counts and percentages of clinical bacterial isolates collected from KFMC for six months during 2021–2022**

Antibiotics	Month 11	Month 12	Month 1	Month 2	Month 3	Month 4	Total
	%	%	%	%	%	%	%
1. Ampicillin	115	113	101	103	80	107	619
	79.3	81.9	75.4	75.7	88.9	89.2	81.7
2. Amoxicillin/Clavulanic acid	90	88	85	87	52	68	470
	62.1	63.8	63.4	64.0	57.8	56.7	61.3
3. Pipercillin/Tazobactam	81	80	74	74	46	59	414
	55.9	58.0	55.2	54.4	51.1	49.2	54.0
4. Cefalotin	80	79	64	64	63	86	436
	55.2	57.2	47.8	47.1	70.0	71.7	58.2
5. Cefoxitin	77	76	64	64	62	84	427
	53.1	55.1	47.8	47.1	68.9	70.0	57.0
6. Ceftazidime	77	76	61	61	58	78	411
	53.1	55.1	45.5	44.9	64.4	65.0	54.7
7. Ceftriaxone	77	76	59	59	63	87	421
	53.1	55.1	44.0	43.4	70.0	72.5	56.4
8. Cefepime	68	67	49	49	53	71	357
	46.9	48.6	36.6	36.0	58.9	59.2	47.7
9. Ceftolozane/Tazobactam	68	67	49	49	53	70	356
	46.9	48.6	36.6	36.0	58.9	58.3	47.6
10. Imipenem	38	37	29	29	42	54	229
	26.2	26.8	21.6	21.3	46.7	45.0	31.3
11. Meropenem	33	32	22	22.0	40	52	201
	22.8	23.2	16.4	16.2	44.4	43.3	27.7
12. Amikacin	70	68	46	46	29	38	297
	48.3	49.3	34.3	33.8	32.2	31.7	38.3
13. Gentamicin	63	62	46	46	39	53	309
	43.4	44.9	34.3	33.8	43.3	44.2	40.7
14. Ciprofloxacin	64	62	67	67	58	75	393
	44.1	44.9	50.0	49.3	64.4	62.5	52.5
15. Tigecycline	22	21	14	14	25	32	128
	15.2	15.2	10.4	10.3	27.8	26.7	17.6
16. Nitrofurantoin	98	96	89	89	54	69	495
	67.6	69.6	66.4	65.4	60.0	57.5	64.4
17. Trimethoprim/Sulfamethoxazole	104	101	81	81	54	71	492
	71.7	73.2	60.4	59.6	60.0	59.2	64.0
18. Azetronam	69	68	60	61	90	120	468
	47.4	49.1	44.6	44.6	100.0	100.0	64.3
19. Colistin	53	50	24	24	52	70	273
	36.4	36.4	17.6	17.6	58.3	58.3	37.4
P-value				0.00			

Most GNB in this study was *E. coli* (n = 290), accounting approximately for 38% of the GNB growth and these results were in line with previous national studies.[6,14,15] The second predominant isolates of GNB were the *K. pneumoniae* (n = 276, 36.2%), this finding was similar to the bacterial isolates prevalence at study from Dhahran.[16] In contrast, from different ICUs at King Khalid University Hospital, the highest prevalence was for *P. aeruginosa* (35.7 %), but the prevalence of *E. coli* was about 22.9% of GNB infection.[17] The third predominant GN pathogen in this study was *P. aeruginosa* (10%) which was in agreement with a recent study, was carried for six years period, which reported

the rate of *P. aeruginosa* as 12.8%.[16] The frequency of non-fermenter GNB at KFMC can be translated into high pathogenicity of *P. aeruginosa* (10.1%) and *A. baumannii* (6.3%), but much lower than a recent local study that represented 37% of GNB causing healthcare associated infections was Non-fermenting Gram-Negative bacteria.[9]

Extended Spectrum Beta-Lactamase (ESBL) production or third-generation cephalosporin (ceftazidime or ceftriaxone) resistance in the current study was reported in 54.7–56.4% of clinical GNB infection at KFMC; 34.1–35.2% of *E. coli*, 53.8–60.3% of *Pseudomonas* spp., 70% of *Klebsiella* spp., and 97.9% of *A. baumannii*, in parallel to the results of an Egyptian study whereas the ESBL production was 16–48.93% of Enterobacteriaceae, 14–87% of *E. coli*, and 19–85.24% of *K. pneumoniae*, respectively.[18] High percentages of the ESBL prevalence in the Gulf Cooperation Council (4–25%), and in the rest of the African countries (9–35%) were recorded.[19] This resistance means that there are fewer antibiotic options available to treat ESBL-producing GNB infections. In many cases, even common contagious diseases caused by third-generation cephalosporin resistance or ESBL-producing germs require more complex therapies. Instead of taking oral antibiotics at home, patients with these infections might need hospitalization and intravenous carbapenem antibiotics.[20]

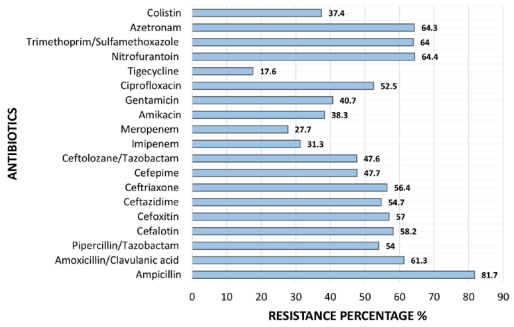

Fig. 2 **Diagram of antibiotics resistance percentages of clinical bacterial isolates collected from KFMC for six months during 2021–2022.**

In this study, 32% of the clinical samples were determined as carbapenem-resistant. However, the rates of carbapenem resistance GNB detection in our study were higher than those previously reported in Saudi Arabia except the study from Al-Jouf rejoin whereas the percentage of carbapenem resistant among Enterobacterales was 32% in 2019.[20] The carbapenem resistance percentages were 26.1% of rectal swabs in Gulf Cooperation Council, 23.2% of clinical isolates in Riyadh and Al-Qassim, 21.7% of clinical isolates in Makkah.[21-23] The carbapenem resistance percentage in our study among all clinical specimens was 1.8% (236/13,501 clinical samples) which was lower than the percentage reported from Al-Qatif city which was 2.8% of all the patients.[24]

Tigecycline resistance and colistin resistance at KFMC were 17.6% and 37.4%, respectively. In more detail, the highest resistance rate to tigecycline was observed in *A. baumannii* (100%), *Pseudomonas* spp. (38.5%), and *Klebsiella* spp. (15.5%), in agreement with the tigecycline resistance rate of GNB (5–18.5%) in recent national studies (Alhumaid et al., 2021; Bandy and Almaeen, 2020), which was much

Table 3. **Counts and resistance percentages of clinical *E. coli* and *Klebsiella* spp. collected from KFMC for 19 antibiotics**

Antibiotics	*E. coli*				*Klebsiella* spp.			
	R	I	S	Resistance prevalence	R	I	S	Resistance prevalence
1. Ampicillin	210	2	78	72.4%	252	0	31	89.0%
2. Amoxicillin/Clavulanic acid	130	0	160	44.8%	207	5	71	73.1%
3. Pipercillin/Tazobactam	92	0	198	31.7%	208	2	73	73.5%
4. Cefalotin	108	2	180	37.2%	202	0	81	71.4%
5. Cefoxitin	106	0	184	36.6%	200	0	83	70.7%
6. Ceftazidime	99	0	191	34.1%	198	0	85	70.0%
7. Ceftriaxone	102	1	187	35.2%	198	0	85	70.0%
8. Cefepime	73	3	214	25.2%	188	0	95	66.4%
9. Ceftolozane/Tazobactam	73	0	217	25.2%	185	0	98	65.4%
10. Imipenem	0	0	290	0.0	149	6	128	52.7%
11. Meropenem	3	2	285	1.0%	135	8	140	47.7%
12. Amikacin	51	0	239	17.6%	167	2	114	59.0%
13. Gentamicin	46	0	244	15.9%	166	1	116	58.7%
14. Ciprofloxacin	77	0	213	26.6%	209	0	74	73.9%
15. Tigecycline	10	2	278	3.4%	44	51	188	15.5%
16. Nitrofurantoin	134	4	152	46.2%	228	9	46	80.6%
17. Trimethoprim/Sulfamethoxazole	157	0	133	54.1%	213	0	70	75.3%
18. Azetronam	97	0	193	33.4%	177	0	106	62.7%
19. Colistin	34	0	256	11.7%	154	17	112	54.5%

S: sensitive; R: resistant; I: intermediate resistant.

Table 4. **Count and resistance percentage of clinical *A. baumannii* and *Pseudomonas spp.* for six months from KFMC for 19 antibiotics**

Antibiotics	*A. baumannii*				*Pseudomonas spp.*			
	R	I	S	Resistance prevalence	R	I	S	Resistance prevalence
1. Ampicillin	48	0	0	100%	67	0	11	85.9%
2. Amoxicillin/Clavulanic acid	44	0	4	91.7%	60	2	16	76.9%
3. Pipercillin/Tazobactam	43	0	5	89.6%	41	3	34	52.6%
4. Cefalotin	47	0	1	97.9%	52	0	26	66.7%
5. Cefoxitin	47	0	1	97.9%	49	0	29	62.8%
6. Ceftazidime	47	0	1	97.9%	42	0	36	53.8%
7. Ceftriaxone	47	0	1	97.9%	47	0	31	60.3%
8. Cefepime	42	0	6	87.5%	36	0	42	46.2%
9. Ceftolozane/Tazobactam	42	0	6	87.5%	36	0	42	46.2%
10. Imipenem	38	0	10	79.2%	28	2	48	35.9%
11. Meropenem	35	1	13	75%	19	5	54	24.4%
12. Amikacin	40	0	8	83.3%	26	3	49	33.3%
13. Gentamicin	45	0	3	94.7%	32	1	45	41.0%
14. Ciprofloxacin	6	0	42	12.5%	40	0	38	51.3%
15. Tigecycline	48	0	0	100%	30	2	46	38.5%
16. Nitrofurantoin	44	0	4	91.7%	59	1	18	75.6%
17. Trimethoprim/Sulfamethoxazole	43	0	5	89.6%	50	0	28	64.1%
18. Azetronam	47	0	1	97.9%	37	0	41	47.4%
19. Colistin	47	0	1	97.9%	24	0	54	30.8%

S: sensitive; R: resistant; I: intermediate resistant.

lower thanthe obtained percentages from an earlier study from Riyadh which reported the resistance rate to tigecycline among GNB infection (33%). They added that recorded percentages were 50% to *E. cloacae* and 43% to *A. baumannii*.[25] In this study, colistin resistance was 37.4% in parallel to the colistin resistance rate of GNB infection in Southwest Saudi Arabia (30%) (Ibrahim, 2018) and it was higher than many previous studies.[26-28] The highest resistance rate to colistin was observed in *A. baumannii* (97.9%), *Klebsiella* spp. (54.5%), and *Pseudomonas* spp. (30.8%), while the highest resistance rate to colistin was observed in *P. mirabilis* (88%), then *Morganella morganii* (66%), and *Stenotrophomonas maltophilia* (17%) in an earlier Saudi study.[25] Ciprofloxacin resistance frequency was about 53%, higher than the ciprofloxacin resistance in an earlier study among blood isolates was about 33% for *E. coli, K. pneumoniae*, and *P. aeruginosa* in 2002–2006.[29] Despite this, the resistance pattern to ciprofloxacin did not change significantly overtime from 2013 to 2018.[16]

In conclusion, antibiotic resistance among *K. pneumoniae*, *P. aeruginosa* and *A. baumannii* were considerably high for many antibiotics including cephalosporins, carbapenems, colistin and tigecycline. Continued surveillance and a multifactorial approach including antibiotic stewardship remain important aspects to limit the increasing antimicrobial resistance in pathogenic GNB in Saudi Arabian hospitals.

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