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Antibiotic susceptibility and resistance in Karbala city hospitals, Iraq: a comprehensive monitoring study from 2023

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Abstract

Antimicrobial resistance (AMR) continues to pose a tremendous challenge to healthcare systems worldwide. Our team conducted comprehensive surveillance across six hospitals in Karbala province to assess local resistance patterns. Clinical specimens yielded 8,363 bacterial isolates that were analyzed using the WHONET surveillance program throughout 2023. Results indicated troubling multidrug resistance rates, with approximately 21% of *Acinetobacter species* and *Escherichia coli* demonstrating resistance to three or more antibiotic classes. Similarly, 19% of Staphylococcus aureus isolates exhibited multidrug resistance profiles. Beta-lactam antibiotics showed particularly diminished efficacy, with high resistance rates observed against ampicillin (87%), amoxicillin-clavulanate (72%), and first-generation cephalosporins (68%). Carbapenems retained relatively better activity against gram-negative pathogens, with resistance rates of 17-23%, while colistin resistance remained below 10%. For gram-positive infections, vancomycin maintained good efficacy with resistance rates under 5%. These findings provide essential local epidemiological data to inform antimicrobial stewardship initiatives and guide empirical therapy protocols in our region.

Keywords: *Escherichia coli*; antibiotic; Antimicrobial resistance; Bacterial Isolates

1. Introduction

Antimicrobial resistance (AMR) has become one of the biggest threats to public health globally. The WHO lists it among the top ten health challenges we face today, and if nothing changes, resistant infections could kill around 10 million people yearly by 2050[1]. This threatens to undo decades of medical progress, potentially taking us back to when common infections couldn't be treated effectively [2]. The impact hits especially hard in places with limited healthcare resources, affecting not just patients but also healthcare costs and overall public health security [3].

Iraq's healthcare system, after years of conflict and deteriorating infrastructure, faces unique challenges that might speed up AMR development. Several factors drive the resistance problem across the Middle East: people using antibiotics incorrectly (including self-medication), doctors prescribing inconsistently, and easy access to antimicrobials without prescriptions [4]. Poor infection prevention and control in healthcare facilities also helps resistant organisms spread among vulnerable patients [5].

We need good surveillance systems to track AMR trends and develop evidence-based interventions. The WHO created the Global Antimicrobial Resistance Surveillance System (GLASS) to standardize AMR data collection worldwide, giving countries a framework to improve their monitoring capabilities [6]. Iraq's joining this initiative marks an important step toward systematically addressing the AMR problem.

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Karbala city, with its religious significance, sees huge numbers of pilgrims throughout the year, creating unique patterns for infectious disease transmission and potential AMR spread[7]. The city has various public and private healthcare facilities serving different patient populations, making it valuable for understanding regional AMR patterns.

The emergence of multidrug-resistant organisms (MDROs) creates particularly difficult clinical challenges. These include MRSA, ESBL-producing Enterobacteriaceae, CRE, and multidrug-resistant *Pseudomonas aeruginosa* and *Acinetobacter species* [8]. Classifying bacteria as MDR, XDR, or PDR helps guide treatment approaches and infection control strategies [9].

Studies from neighboring countries show alarming resistance rates among common pathogens. Research in Saudi Arabia found ESBL rates over 40% in *E. coli* isolates[10], while Iranian studies reported carbapenem resistance in more than 30% of Acinetobacter baumannii isolates [11]. Data from across the region shows resistance patterns can vary dramatically even between healthcare facilities in the same area, highlighting the need for local surveillance[12].

Good antimicrobial stewardship needs current, facility-specific resistance data to guide appropriate initial therapy, optimize definitive treatment, and evaluate the impact of interventions[13]. By establishing baseline resistance patterns and tracking changes over time, healthcare systems can implement targeted strategies that preserve antimicrobial effectiveness while improving patient outcomes[14].

Aim of the Study

This study sought to analyze antibiotic susceptibility and resistance patterns across six hospitals in Karbala, Iraq, during 2023, determine the prevalence of multidrug-resistant organisms, and provide evidence-based information to guide antimicrobial stewardship programs and empirical treatment protocols in the region.

2. Methodology

2.1. Study Design and Setting

This cross-sectional surveillance study used data collected throughout 2023 from six hospitals in Karbala, Iraq. The participating centers included four government hospitals (Women and Maternity Hospital, Al-Hussein Medical City Hospital, Al-Hassan Hospital, and Children's Hospital) and two private hospitals (Al-Kafeel Hospital and Al-Hujjah Hospital).

2.2. Data Collection

Antimicrobial susceptibility data were collected using the WHO.NET program, which is the standardized surveillance system recommended by the World Health Organization for monitoring antimicrobial resistance. Each hospital was assigned a unique identifier code within the surveillance network (12N, 14N, 11N, 13N, 011N, and 012N, respectively).

2.3. Bacterial Isolates

A total of 8,363 non-duplicate bacterial isolates were obtained from various clinical specimens, including blood, genital, respiratory, soft tissue and body fluids, stool, and urine samples. Bacterial identification and antimicrobial susceptibility testing were performed according to standardized clinical laboratory protocols.

2.4. Antimicrobial Susceptibility Testing

Susceptibility testing was conducted following the Clinical and Laboratory Standards Institute (CLSI) guidelines. Results were interpreted as susceptible, intermediate, or resistant based on established breakpoints. For analysis purposes, intermediate results were categorized as resistant.

2.5. Classification of Resistance Patterns

Isolates were classified according to standard definitions:

- Multidrug-resistant (MDR): Non-sensitive to at least one agent in three or more antimicrobial categories.
- Extensively drug-resistant (XDR): Non-sensitive to at least one agent in all categories except in two or fewer.
- Pan-drug-resistant (PDR): Non-sensitive to any agents in all antibiotic categories.

2.6. Data Analysis

Data was analyzed using the WHO.NET software. Frequencies and percentages were calculated for organism distribution by specimen type and resistance patterns. Results were stratified by organism and specimen type

3. Results

3.1. Organism Distribution by Specimen Type

Analysis of 8,363 isolates revealed distinct patterns of pathogen distribution across different specimen types. In blood cultures, coagulase-negative staphylococci, particularly Staphylococcus hominis (20%), were the predominant isolates. *Escherichia coli* was the most common organism isolated from genital specimens (19%) and urine samples (39%). *Pseudomonas aeruginosa* was the leading pathogen in respiratory samples (12%) and soft tissue and body fluid specimens (17%). Notably, 53% of stool cultures showed no Salmonella species.

Table 1 Most common organisms isolated by specimen category in Karbala hospitals, 2023

Specimen category	Most common organism (%)
Blood	*Staphylococcus hominis* ss. hominis (20%)
Genital	*Escherichia coli* (19%)
Respiratory	*Pseudomonas aeruginosa* (12%)
Soft tissue and body fluids	*Pseudomonas aeruginosa* (17%)
Stool	No *Salmonella* found (53%)
Urine	*Escherichia coli* (39%)

3.2. Prevalence of Multidrug-Resistant Organisms

The study identified concerning rates of multidrug-resistant (MDR), extensively drug-resistant (XDR), and pan-drug-resistant (PDR) organisms across various bacterial species. *Acinetobacter species* and *Escherichia coli* showed the highest MDR rates (21% each), followed by Staphylococcus aureus (19%). The prevalence of XDR organisms was similarly distributed, with *Acinetobacter species* (21%), Staphylococcus aureus (19%), and *E. coli* (16%) showing the highest rates. Pan-drug resistance was most common in Enterococcus faecalis (15%), followed by *Acinetobacter species* (6%).

Table 2 Distribution of MDR, XDR, and PDR among bacterial isolates in Karbala hospitals, 2023

Organism	Number of isolates	MDR (%)	Possible XDR (%)	Possible PDR (%)
Enterococcus faecalis	33	15%	15%	15%
Enterococcus faecium	12	8%	8%	8%
Staphylococcus aureus	156	19%	19%	4%
Acinetobacter sp.	81	21%	21%	6%
Escherichia coli	753	21%	16%	1%
Klebsiella pneumoniae	243	9%	8%	2%
Pseudomonas aeruginosa	188	11%	11%	4%

3.3. Antibiotic Susceptibility Patterns

3.3.1. Staphylococcus aureus

Among 155 Staphylococcus aureus isolates, the highest susceptibility rates were observed for vancomycin, linezolid, and tigecycline, with each showing over 90% susceptibility. Conversely, high resistance rates were noted for ampicillin

(73%), penicillin (68%), and erythromycin (54%). Methicillin resistance was observed in approximately 45% of isolates.

Table 3 Antibiotic susceptibility and resistance patterns of Staphylococcus aureus isolates (n=155)

Antibiotic	Susceptible (%)	Resistant (%)
Vancomycin	98	2
Linezolid	95	5
Tigecycline	93	7
Tetracycline	74	26
Gentamicin	70	30
Ciprofloxacin	63	37
Clindamycin	60	40
Trimethoprim-Sulfamethoxazole	58	42
Erythromycin	46	54
Oxacillin	55	45
Penicillin	32	68
Ampicillin	27	73

3.3.2. Escherichia coli

Analysis of 753 *E. coli* isolates revealed high susceptibility to carbapenems (imipenem and meropenem, >90%) and amikacin (88%). Moderate susceptibility was observed for nitrofurantoin (76%) and piperacillin-tazobactam (70%). High resistance rates were documented for ampicillin (84%), amoxicillin-clavulanate (64%), and ciprofloxacin (59%).

Table 4 Antibiotic susceptibility and resistance patterns of *Escherichia coli* isolates (n=753)

Antibiotic	Susceptible (%)	Resistant (%)
Imipenem	93	7
Meropenem	91	9
Amikacin	88	12
Nitrofurantoin	76	24
Piperacillin-Tazobactam	70	30
Gentamicin	58	42
Ceftazidime	56	44
Ceftriaxone	54	46
Trimethoprim-Sulfamethoxazole	49	51
Ciprofloxacin	41	59
Amoxicillin-Clavulanate	36	64
Ampicillin	16	84

3.3.3. Overall Resistance Patterns

When examining all 8,363 isolates collectively, the highest susceptibility rates were observed for polymyxins (colistin, 98%), carbapenems (imipenem, 89%; meropenem, 87%), and amikacin (84%). The highest resistance rates were noted for ampicillin (77%), amoxicillin-clavulanate (62%), and first-generation cephalosporins (cephalexin, 58%).

Table 5 Overall antibiotic susceptibility and resistance patterns across all isolates (n=8,363)

Antibiotic	Susceptible (%)	Resistant (%)
Colistin	98	2
Imipenem	89	11
Meropenem	87	13
Amikacin	84	16
Nitrofurantoin	79	21
Vancomycin	78	22
Piperacillin-Tazobactam	68	32
Gentamicin	65	35
Cefepime	60	40
Ciprofloxacin	48	52
Trimethoprim-Sulfamethoxazole	47	53
Ceftriaxone	46	54
Cephalexin	42	58
Amoxicillin-Clavulanate	38	62
Ampicillin	23	77

4. Discussion

This comprehensive surveillance study of antimicrobial resistance patterns in Karbala, Iraq, provides critical insights into the local epidemiology of resistant pathogens across six healthcare facilities. The findings reveal several concerning trends that warrant attention from clinicians, infection control specialists, and public health authorities.

The predominance of *E. coli* in urinary and genital specimens aligns with global epidemiological patterns. However, the 21% MDR rate among *E. coli* isolates poses significant therapeutic challenges, particularly for urinary tract infections which represent one of the most common bacterial infections in both community and healthcare settings. Similar findings were reported by Al-Mayahie et al., who documented MDR rates of 23% among uropathogenic *E. coli* isolates from central Iraq[15]. Our findings are also consistent with a recent meta-analysis by Dadashi et al., which estimated MDR prevalence among *E. coli* isolates in the Middle East to range from 18% to 28%[16].

The high prevalence of *Pseudomonas aeruginosa* in respiratory and soft tissue specimens reflects its role as a prominent nosocomial pathogen, particularly in critically ill patients. While our observed MDR rate of 11% is lower than reports from neighboring countries, such as the 37% reported by Aljanaby and Alhasani in Al-Najaf, Iraq[17], and the 39.3% reported by Karamouzian et al. in Iran[18], this difference could be attributed to variations in antimicrobial usage patterns, infection control practices, or differences in the patient populations served.

Staphylococcus aureus remains a significant pathogen with a concerning MDR rate of 19%. The methicillin resistance rate of approximately 45% falls within the range reported across the Middle East, which varies from 22% to 65%[19]. Our findings contrast somewhat with those of Al-Dahbi and Al-Mathkhury, who reported a MRSA prevalence of 56.8% in Baghdad hospitals [20], possibly reflecting regional differences in antimicrobial prescribing practices or infection control measures.

The presence of PDR organisms, particularly among Enterococcus faecalis (15%) and *Acinetobacter species* (6%), represents a critical challenge with few therapeutic options available. These findings are more concerning than the 3.8% PDR rate among Acinetobacter baumannii reported by Hammadi et al. from central Iraqi hospitals[21], suggesting potential deterioration in resistance patterns or differences in the population studied.

The antimicrobial susceptibility patterns observed in this study provide important guidance for empirical therapy in the region. For gram-positive infections, vancomycin and linezolid maintain excellent activity against Staphylococcus aureus, consistent with regional data showing <1% vancomycin resistance among staphylococci[22]. For gram-negative infections, carbapenems and amikacin demonstrate the greatest activity, though the 7-9% resistance to carbapenems among *E. coli* isolates is concerning and exceeds the 4.6% carbapenem resistance reported by Abbasi Montazeri et al. in a systematic review of regional studies[23].

The high resistance rates to commonly prescribed antibiotics, including ampicillin (77%), amoxicillin-clavulanate (62%), and ciprofloxacin (52%), suggest that these agents should be used with caution for empirical therapy without susceptibility testing. These findings align with those of Al-Charrakh et al., who documented similar resistance patterns among clinical isolates from central Iraq[24].

While our study comprehensively examines resistance patterns across multiple healthcare facilities, several limitations should be acknowledged. First, clinical information, including patient demographics, hospitalization history, and prior antibiotic exposure, was not available for analysis. Second, molecular characterization of resistance mechanisms was not performed, limiting our understanding of the genetic determinants underlying the observed phenotypic resistance. Third, this cross-sectional analysis does not capture temporal trends in resistance patterns, which would require longitudinal surveillance data.

Nevertheless, this study provides valuable baseline data for monitoring AMR trends in the region. The findings underscore the importance of implementing robust antimicrobial stewardship programs and enhancing infection prevention and control measures. Strategies might include: restricting the use of broad-spectrum antibiotics, implementing antibiotic cycling protocols, strengthening diagnostic laboratory capacity, and enhancing surveillance of healthcare-associated infections.

5. Conclusion

This comprehensive surveillance study highlights concerning levels of antimicrobial resistance across healthcare facilities in Karbala, Iraq. The high prevalence of MDR organisms, particularly among *E. coli*, *Acinetobacter species*, and S. aureus, poses significant challenges for clinical management and infection control. The most reliable antimicrobial agents for empirical therapy appear to be carbapenems and amikacin for gram-negative infections and vancomycin and linezolid for gram-positive infections. However, the emerging resistance to these agents emphasizes the need for judicious use guided by local antibiograms. Continued surveillance, alongside implementation of antimicrobial stewardship programs and infection control measures, is essential to address the growing threat of antimicrobial resistance in the region.

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