

Original Research Article

Prevalence and resistance patterns of multidrug-resistant *Acinetobacter baumannii* in clinical samples from Diyala, Iraq

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Abstract

Purpose: To address the surveillance gap in Iraq by tracking the prevalence, trends, and patterns of *Acinetobacter baumannii* (A. baumannii) resistance at Diyala Province, Iraq.

Methods: A total of 300 clinical samples comprising burns, wounds, sputum and urine were collected from patients visiting the outpatient unit of Baqubah Teaching Hospital, Diyala Province, Iraq, from May to December 2024. Cultures were performed on blood agar, MacConkey agar, and Chrome agar, followed by diagnostic confirmation using biochemical tests and the VITEK® Compact system.

Results: Of the 300 specimens collected from both males and females across a range of clinical samples, only 50 (16.7 %) contained A. baumannii isolates. Of these, 22 (7.3 %) A. baumannii bacterial isolates occurred in wound samples, 16 (5.3 %) A. baumannii isolates occurred in burn swab samples, 7 (2.4 %) and 5 (1.7 %) isolates were from urine and sputum samples, respectively. A total of 216 samples (72 %) yielded other bacterial species, while 34 samples (11.3 %) showed no bacterial growth. Fifty bacterial isolates of A. baumannii were obtained after local isolates that belonged to multidrug resistance (MDR) or extensively drug resistance (XDR) group were identified. All 50 samples (100 %) were MDR, whereas 16 isolates (84.2 %) were XDR.

Conclusion: Specimens from burns and wounds contain A. baumannii, with 100 % of isolates being multidrug resistant and 84.2 % extremely drug-resistant. This highlights the limited effectiveness of antibiotics and necessitates targeted actions to prevent the spread of the microorganism.

Keywords: *Acinetobacter baumannii*, Multidrug resistance, Carbapenem resistance, Antibiotic resistance, extensively drug-resistant

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INTRODUCTION

Acinetobacter baumannii (A. baumannii) is a gram-negative opportunistic pathogen that has become a major cause of healthcare-associated infections, especially in intensive care units (ICUs) [1]. This bacterium is notable for its ability to survive on abiotic surfaces, tolerating desiccation and ability to gain resistance

determinants by horizontal gene transfer, hence persisting in clinical settings [2]. *Acinetobacter baumannii* infection causes pneumonia, urinary tract infection, bacteremia, wound and nervous system infections, which occur in relatively healthy persons or immunocompromised patients or during invasive procedures [3]. *Acinetobacter baumannii* has recently exhibited an alarming ability to rapidly achieve multidrug resistance

(MDR) and extensively drug resistance (XDR), thereby greatly restricting treatment choices [4]. It is also typically resistant to multiple classes of antibiotics, including the β -lactams, aminoglycosides, fluoroquinolones, and even the members of the carbapenem class, typically an antibiotic class reserved for last-line treatment [5].

Globally, the rise of carbapenem-resistant *A. baumannii* (CRAB) strains is a serious public health issue, with developing countries being disproportionately affected because of weaker antimicrobial stewardship programs and detection capabilities [6]. In Iraq, district-level data on the prevalence and resistance profiles of *A. baumannii* and also data on resistance profiles of *A. baumannii* are lacking as many of the studies are old or in limited clinical environments [7]. This absence of complete practice-level surveillance data limits the ability to implement evidence-based infection control policies and targeted antimicrobial therapy. This study, therefore, was conducted to explore the occurrence of *A. baumannii* in clinical samples from different patients visiting government hospitals in Diyala, Iraq, together with the determination of the drug susceptibility for each isolate. Secondly, this study aims to distinguish MDR from XDR isolates according to international standards [8]. These findings are expected to fill the existing gap in knowledge and help in the development of effective infection prevention strategies and antibiotic stewardship policy for healthcare facilities in Iraq [9].

METHODS

Study design and sample collection

This cross-sectional study was carried out in the outpatient unit of government hospitals in Baqubah, Diyala Province, Iraq, from May to December 2024. A total of 300 clinical specimens were taken from patients who reported to the hospital with various disease conditions such as skin or flesh wounds, burns, coughs, respiratory and urinary tract disorders and other disorders that expose sterile body tissues to bacterial contamination. Microbiological investigation of wound swabs, burn swabs, sputum, and urine specimens collected from affected and consenting patients was conducted in the microbiology lab of the same hospital.

Bacterial isolation and culture media

Every sample collected was cultivated on blood agar, MacConkey agar, and CHROM agar for 24

to 48 hours, in plates incubated aerobically at 37 °C. Hemolytic activity, colony shape, and pigmentation were observed. MacConkey agar was used to measure lactose fermentation, and blood agar was used to measure hemolysis. Colonies that were thought to be *A. baumannii* were identified further [10].

Phenotypic identification of *A. baumannii*

In addition to traditional biochemical tests like catalase, oxidase, indole synthesis, citrate consumption, urease, triple sugar iron (TSI), methyl red, and Voges-Proskauer assays, preliminary identification was based on colony shape and Gram staining. Using automated techniques, gram-negative coccobacilli that were non-lactose fermenting, catalase-positive, and oxidase-negative were further examined [11].

Automated identification using the VITEK-2 system

The VITEK 2 compact system (bioMérieux, France) was used to confirm the isolates of *A. baumannii* using Gram-negative (GN) identification cards specifically designed for Gram-negative bacteria. The system was calibrated and run in accordance with the manufacturer's instructions.

Antimicrobial susceptibility testing (AST)

The Bau-Kirby disk diffusion method was used to determine the sensitivity of *A. Baumannii* bacteria to antibiotics. Mueller-Hinton agar medium was used for this test. Three to five colonies were grown on nutrient agar and then transferred to tubes containing normal saline until the MacFarland standard turbidity (1.5×10^8 CFU/mL) was achieved.

A sterile swab was inserted into a tube containing a bacterial suspension. It was rotated and pressed against the inner walls of the tube to remove excess suspension. It was then distributed across Petri dishes containing Mueller-Hinton agar in different directions to ensure homogeneous growth. The antibiotic discs used in the study mentioned in Table 1 were placed on the surface of the culture media at an equal distance from each other and pressed using sterile forceps.

They were stored at 37 °C for 24 h. The results were read by measuring the diameter of the inhibition zone around the antibiotic discs and then comparing it to the standard inhibition zone [12,13].

Table 1: The antibiotic discs and their respective concentrations (Origin Bioanalyse, Turkey)

Class	Group	Antibiotics	Code	Disc (µg)
β-lactam	Pencillines	Piperacillin	PRL	100
		Cephems	Ceftazidime	CAZ
		Cefepime	FEP	10
		Cefotaxime	CTX	10
		Ceftriaxone	CRO	10
	Carbapenems	Imipenem	IMP	10
		Meropenem	MEM	10
	β-lactam combination agents	Ampicillin –sulbactam	AMS	20
		Piperacillin –tazobactam	TPZ	110
		Ticarcillin –clavulanic acid	TTC	85
Aminoglycosides	Gentamicin	CN	10	
	Amikacin	AK	10	
Fluoroquinolones	Ciprofloxacin	CIP	10	
	Levofloxacin	LEV	5	

Biofilm-forming when tested using the Congo red method

Biofilm formation was phenotypically evaluated using the Congo Red Agar (CRA) method, a qualitative screening technique widely used to determine slime and exopolysaccharide (EPS) production in bacterial isolates [14]. This method is based on the ability of biofilm-producing bacteria to bind Congo red dye in the presence of sucrose, resulting in distinct colony colour changes. Principal Biofilm-forming bacteria synthesise extracellular polysaccharides that interact with Congo red dye, producing black or dark colonies, whereas non-biofilm producers form red or pink colonies. The reaction reflects the expression of biofilm-associated genes involved in EPS production.

Detection of biofilm by the microtiter plate method

The microtiter plate (MTP) assay is based on the ability of bacteria to adhere to the wells of a polystyrene microtiter plate and form biofilms. Bacterial isolates were inoculated in 96-well flat-bottom polystyrene microtiter plates and grown overnight in tryptic soy broth (TSB) ± 1 % glucose (or appropriate growth medium) at 37 °C. Cultures were then diluted 1:100 in fresh, sterile TSB supplemented with 1% glucose to enhance biofilm formation. Samples were stained with crystal violet solution (0.5 – 1.0 %), further diluted with phosphate-buffered saline (PBS) and measured spectrophotometrically in a microplate reader at a wavelength of 570 or 595 nm.

Phenotypic determination of metallo-beta-lactamase production by the combined EDTA disc test (CEDT)

The CEDT test was employed for the phenotypic determinations of metallo-beta-lactamases (MBLs) in *A. baumannii* isolates by following the

manufacturer's instructions. Isolates demonstrating a ≥ 7 mm increase in the inhibition zone diameter around imipenem-EDTA disc compared to imipenem disc alone were classified as MBL producers.

Statistical analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Chi-square test was used to evaluate the association between *A. baumannii* occurrence and clinical sample types. A *p*-value < 0.05 was considered statistically significant.

RESULTS

Isolation and identification of *Acinetobacter baumannii*

Out of the 300 clinical specimens analyzed, *A. baumannii* was isolated from 50 of these clinical samples (16.7 %). The highest number of isolates was recovered from wound swabs (22 isolates; 7.3 %), followed by burn swabs (16 isolates; 5.3 %), urine samples (7 isolates; 2.4 %), and sputum samples (5 isolates; 1.7 %). A total of 216 samples (72 %) yielded other bacterial species, while 34 samples (11.3 %) showed no bacterial growth. Although wound and burn samples yielded more *A. baumannii* isolates, the association between sample type and isolation rate was not statistically significant (Chi-square = 10.07, *p* = 0.12). These results are shown in Table 2.

Identification of *Acinetobacter baumannii*

On MacConkey agar, all 50 isolates of *A. baumannii* showed spherical, pale colonies and did not digest lactose.

Table 2: Distribution of the diagnosis of bacteria from the clinical samples

Clinical samples	Diagnosis of bacteria			P-value
	<i>A. baumannii</i>	Other species	No growth	
Wound swabs	22 (7.3)	75 (25.0)	5 (1.7)	0.12
Burn	16 (5.3)	72 (24.0)	13 (4.3)	
Urine	7 (2.4)	43 (14.3)	9 (3.0)	
Sputum	5 (1.7)	26 (8.7)	7 (2.3)	
Total	50 (16.7)	216 (72.0)	34 (11.3)	

Values are n (%); n=300. *Other species of bacterial isolates were not mentioned, as they were not the subject of the study. Chi-square = 10.07

The colonies were either grey or white and looked convex on blood agar. Interestingly, because the hemolysin enzyme was absent, they did not result in blood lysis. *A. baumannii* was specifically isolated using CHROM agar. *A. baumannii* isolates showed a characteristic pale purple color with a halo on CHROM agar, as illustrated in Figure 1 and shown in Table 3.

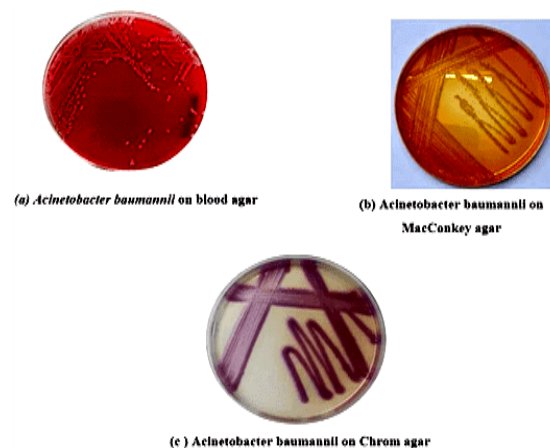


Figure 1: Growth characteristics of *A. baumannii* isolates on Blood agar (a), MacConkey agar (b), and CHROM agar (c)

All isolates obtained from MacConkey agar media were identified as *A. baumannii* based on Gram staining, which revealed gram-negative

coccobacilli arranged in diplococci, as shown in Figure 2.

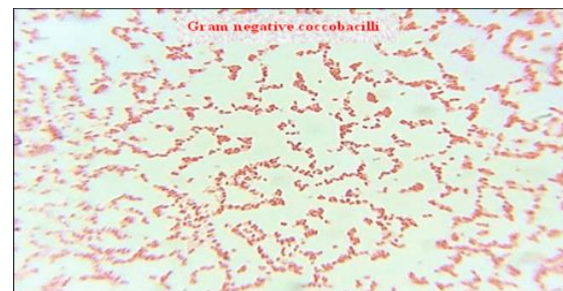


Figure 2: Gram stain for *Acinetobacter baumannii*

Antibiogram pattern of *Acinetobacter baumannii*

Clinical isolates of *A. baumannii* showed significant resistance to the majority of the antibiotics that were examined ($p < 0.05$). In particular, isolates of *A. baumannii* showed complete resistance 50 (100 %) to gentamicin, ampicillin-sulbactam, piperacillin-tazobactam, ceftazidime, cefepime, cefotaxime, and ceftriaxone. Furthermore, amikacin 48 (96.0 %), imipenem and meropenem 38 (76.0 %), levofloxacin 33 (66.0 %), and ciprofloxacin 32 (64.0 %) also showed some resistance, as shown in Figure 3.

Table 3: Traditional microbiological detection methods of *Acinetobacter baumannii*

Media and test	Results
Growth on MacConkey agar	+
Lactose fermentation	-
Growth of chrome agar	+
Gram stain	-
Catalase	+
Oxidase	-
Indol production	-
Methyl red	-
Voges -Proskauer	-
Citrate utilization test	+
Triple sugar iron agar	K/K -, - No fermentation, no hydrogen sulphide production, no gas

*(+) Positive test and (-) Negative test

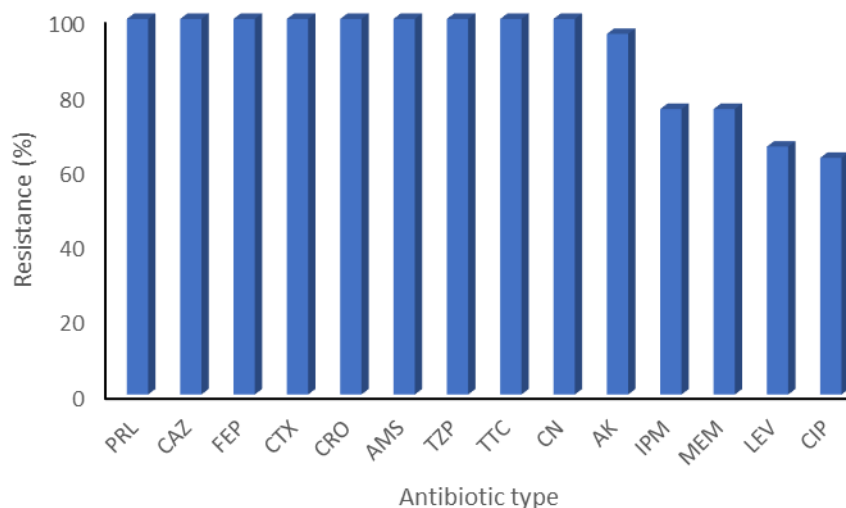


Figure 3: *Acinetobacter baumannii* profile of antibiotic susceptibility (n = 50). Ceftazidime (CAZ), Cefepime (FEP), Cefotaxime (CTX), Ceftriaxone (CRO), Ampicillin-sulbactam (AMS), Piperacillin-tazobactam (TZP), Ticarcillin-clavulanic acid (TTC), Gentamicin (CN), Amikacin (AK), Ipanema (IPM), Meropenem (MEM), Levofloxacin (LEV), Ciprofloxacin (CIP)

Distribution of the isolate according to multidrug resistance

Based on the current data, 31 out of the 50 isolates (62.0 %) were identified as XDR and 19 isolates (38.0 %) as MDR.

Biofilm formation in *Acinetobacter baumannii*

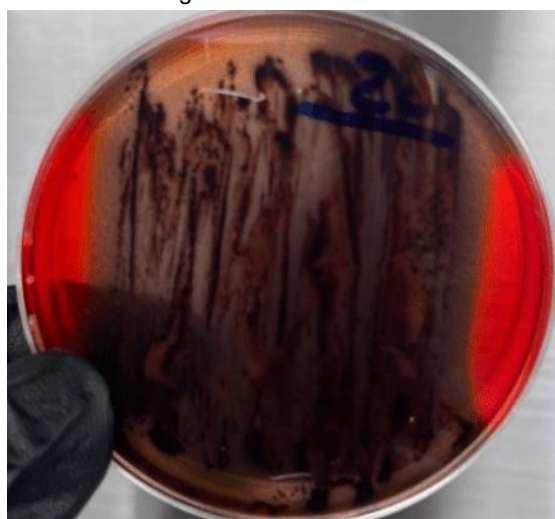
A total of 26 out of 50 (52.0 %) *A. baumannii* isolates were classified as non-biofilm-forming, while the remaining 24 (48.0 %) isolates were categorised as biofilm-forming when tested using

the Congo red method, as illustrated in Figure 4 a, b.

Biofilm determination

Results of absorbance reveal that 9 out of 50 (18.0 %) *A. baumannii* isolates were classified as weak/non-biofilm formation, while 22 out of 50 (44.0 %) were categorized as moderate biofilm formers. In contrast, 19 out of 50 (38.0 %) isolates were scored as strong biofilm formers when assessed using the microtiter plate method, as illustrated in Figure 5.

a. Biofilm forming



b. Non-biofilm forming



Figure 4: Photograph of *A. baumannii* isolates showing (a) biofilm formation and (b) non-biofilm formation

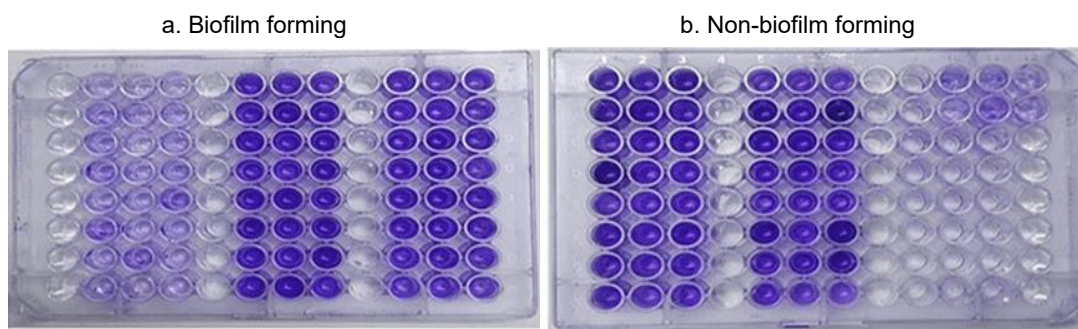


Figure 5: Quantification of Biofilm formation in *A. baumannii* Isolates

Table 3: Correlation between the antibiotic susceptibility status and biofilm formation

Name	Susceptibility status	Biofilm score			Total	P-value
		Weak	Moderate	Strong		
CIP (µg)	S	3 (6.0)	8 (16.0)	7 (14.0)	18 (36.0)	0.3
	R	8 (16.0)	11 (22.0)	13 (26.0)	32 (64.0)	
LEV (µg)	S	3 (6.0)	7 (14.0)	7 (14.0)	17 (34.0)	0.4
	R	5 (10.0)	15 (30.0)	13 (26.0)	33 (66.0)	
AK (µg)	S	0 (0.0)	1 (2.0)	1 (2.0)	2 (4.0)	0.08
	R	17 (34.0)	19 (38.0)	12 (24.0)	48 (96.0)	
CN (µg)	S	-	-	-	-	-
	R	13 (26.0)	24 (48.0)	13 (26.0)	50 (100.0)	
TTC (µg)	S	-	-	-	-	-
	R	11 (22.0)	29 (58.0)	10 (20.0)	50 (100.0)	
TPZ (µg)	S	-	-	-	-	-
	R	12 (24.0)	23 (46.0)	15 (30.0)	50 (100.0)	
AMS (µg)	S	-	-	-	-	-
	R	11 (22.0)	26 (52.0)	13 (26.0)	50 (100.0)	
MEM (µg)	S	2 (4.0)	4 (8.0)	6 (12.0)	12 (24.0)	0.88
	R	6 (12.0)	20 (40.0)	12 (24.0)	38 (76.0)	
IMP (µg)	S	3 (6.0)	6 (12.0)	3 (6.0)	12 (24.0)	0.34
	R	11 (22.0)	18 (36.0)	9 (18.0)	38 (76.0)	
CRO (µg)	S	-	-	-	-	-
	R	18 (36.0)	19 (38.0)	13 (26.0)	50 (100.0)	
CTX (µg)	S	-	-	-	-	-
	R	19 (38.0)	20 (40.0)	11 (22.0)	50 (100.0)	
FEP (µg)	S	-	-	-	-	-
	R	29 (58.0)	18 (36.0)	3 (6.0)	50 (100.0)	
CAZ (µg)	S	-	-	-	-	-
	R	12 (24.0)	19 (38.0)	19 (38.0)	50 (100.0)	
PRL (µg)	S	-	-	-	-	-
	R	18 (36.0)	17 (34.0)	15 (30.0)	50 (100.0)	

Values are n (%); S = susceptible, R = resistant; P-values indicate the significance of the association between susceptibility and biofilm-forming capacity

Metallo-beta-lactamase production

Out of 50 *A. baumannii* isolates, 24 (48.0 %) tested positive for metallo-beta-lactamase, while 26 (52.0 %) tested negative for metallo-beta-lactamase, as illustrated in Figures (6 a and b).

Correlation between the antibiotic susceptibility status and biofilm formation

This dataset shows the relationship between antibiotic susceptibility and biofilm formation strength among isolates exposed to various antibiotics.

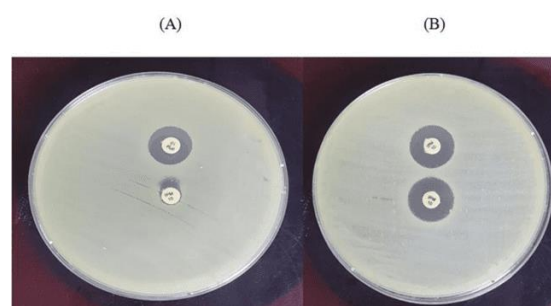


Figure (6): Imipenem EDTA Combined Disc Test (ECDT). (A) MBL positive, (B) MBL negative

Ciprofloxacin (CIP) susceptible isolates (36.0 %) are more frequently weak/moderate biofilm producers. Resistant isolates (64.0 %) are more likely to be strong biofilm producers, while more resistant isolates show stronger biofilm. The difference was not statistically significant ($p > 0.05$), which suggests a trend, but not enough evidence. When using antibiotics (CN, TTC, TPZ, AMS, CRO, CTX, FEP, CAZ, PRL), all resistant isolates were biofilm producers. This is shown in Table 3.

DISCUSSION

A comparative analysis in Iraq revealed modest differences in the distribution of *A. baumannii* isolates [10]. The study involved the collection of 450 clinical samples from intensive care unit (ICU) patients, encompassing specimens such as blood, urine, sputum, wound swabs, burns, and cerebrospinal fluid (CSF). The investigation was carried out across four major hospitals in the Kurdistan region of Iraq and included patients of diverse ages and both genders. Identification of *A. baumannii* isolates was based on standard biochemical testing and confirmed using the VITEK-2 system, which demonstrated a 99 % accuracy. The variation in isolate distribution between their study and the present investigation may be attributed to differences in patient demographics, hospital environments, and sample sources, particularly the focus on ICU settings in the former study.

The isolates from MacConkey agar media were identified as *A. baumannii* by Al-Daraghi and Al-Taliby [15] based on Gram staining, which showed gram-negative coccobacilli grouped in diplococci. All 50 isolates of *A. baumannii* tested negative for the oxidase test, but all tested positive for catalase [11].

Globally, similar resistance patterns have been observed, although rates vary by region. A recent surveillance in India by Banerjee et al reported over 90 % of *A. baumannii* isolates resistant to third-generation cephalosporins and over 70 % to carbapenems, which is comparable to the rates identified in the present investigation [16]. Such comparisons with other countries show that Iraq suffers a higher burden of resistant *A. baumannii* that warrants the use of last-resort drugs like colistin and tigecycline. The worldwide appearance of carbapenem-resistant strains of *A. baumannii* (CRAB) is alarming as they are linked to higher mortality, longer hospital stays, and outbreaks, especially in ICUs. The very high resistance rates in this study indicate an urgent need for national (AMR) control strategies,

including routine molecular screening, regional surveillance and new therapies [17].

Common and widely accepted detection methods include phenotypic systems and commercial phenotypic procedures, including BioMérieux's Vitek-2 system, which has proven successful in identifying a number of *Acinetobacter* species. However, it is crucial to remember that these approaches have inherent drawbacks, as noted by Almaghrabi et al [18] and Lee et al [19]. According to Abdul-Hussein et al the VITEK 2 system accurately recognised all 30 clinical isolates as *A. baumannii* by using the identification card for Gram-negative isolates (IDGNB) [20].

The 62.0 % classification of the *A. baumannii* clinical isolates as extensively drug-resistant (XDR) and 38.0 % as multidrug-resistant (MDR) further emphasizes the increasing danger of antimicrobial resistance in clinical environments. These results show that most of the tested isolates were resistant to at least one agent in all but two or fewer antimicrobial categories, consistent with the XDR definition by the European Center for Disease Prevention and Control (ECDC) and other Centers for Disease Control (CDC) [12]. Such resistance patterns have been observed in Iraq in a study carried out in Erbil [10], where *A. baumannii* isolates, XDR, and their MDR strains reported were comparable with the results of this study. Furthermore, a study from Basrah in 2023 reported high levels (65 %) of XDR among isolates from ICU patients, thereby highlighting the severity of the threat this poses to hospitals in Iraq [20,21]. These similar findings might also be a result of common elements, like inadequate adherence to infection control protocols, extensive use of broad-spectrum antimicrobial agents, as well as the absence of or limited stewardship program options [21].

Global prevalence of XDR *A. baumannii* is discordant but certainly a critical threat. The XDR prevalence was 70 % in Egypt [22], which is marginally higher than the findings in this study, while 58 % of strains in Turkey mirrored the current results with nearly all strains being XDR [23]. Conversely, more healthcare system-regulated countries such as South Korea have achieved lower XDR rates, roughly 30 – 40 % due to strict antimicrobial stewardship and early diagnostics interventions [24]. The maximal proportion of XDR isolates in the current report could be indicative of the fact that Iraq suffers from an unfairly large antibiotic resistance burden compared to some of the neighbouring countries. This highlights the urgent need for national

policies targeting the misuse of antibiotics, surveillance of resistance patterns, and investment in alternative treatments and rapid molecular diagnostics [25]. Biofilm formation in *A. baumannii* poses major challenges in clinical settings, as it enables the bacterium to persist on medical equipment and establishes infections that resist antimicrobial treatments, complicating infection management [26]. The study found that 48.0 % of *Acinetobacter baumannii* clinical isolates formed biofilms, while 52.0 % did not, indicating a moderate prevalence with clinical implications due to biofilms' association with antibiotic resistance and persistence in hospitals. This aligns with similar findings in Iraq: 45 % in Karbala and 52.9 % in Mosul, suggesting regional consistency. Internationally, biofilm formation rates vary, with studies reporting 64 % in India and 70 % in Iran; however, a Turkish study found only 42 %. These variations might be attributed to differences in infection control measures and strain diversity. The results highlight the need for targeted anti-biofilm therapies and enhanced diagnostic screening due to biofilm-forming strains being linked to multidrug resistance and treatment failures [27].

The study showed that 48.0 % of clinical isolates produced biofilms as assessed by the microtiter plate (MTP) method, with classifications of strong, moderate, and weak biofilm producers. Notably, *A. baumannii* isolates were identified as weak, moderate, and strong biofilm producers. A significant correlation between biofilm strength and antibiotic resistance, particularly to aminoglycosides and carbapenems, was observed. Comparisons with prior Iraqi studies revealed consistent biofilm formation rates, reinforcing the clinical relevance of biofilms in persistent infections. Variations in rates may stem from differences in sample sources and methodologies. The findings emphasize the need for effective infection control and anti-biofilm strategies in healthcare settings [28].

The study found that 48 % of *Acinetobacter baumannii* isolates produced metallo-beta-lactamase (MBL), indicating a significant presence of resistant strains. This resistance to beta-lactam antibiotics, including carbapenems, limits treatment options and is associated with higher morbidity and mortality. Regional studies in Baghdad showed 79 % of isolates carried MBL genes, while Ramadi reported 93.2 % phenotypically producing MBL, and Duhok identified 59.2 % as MBL producers. In India, 80.3 % of imipenem-resistant isolates displayed MBL activity, confirming a link between carbapenem resistance and MBL production. Studies from Morocco and Iran reported similar

high prevalence rates. These findings underscore the urgent need for strategies to monitor and control the spread of these resistant strains in healthcare settings.

CONCLUSION

Acinetobacter baumannii is a multidrug-resistant and extensively drug-resistant pathogen. The highest prevalence was found in wound and burn swab samples, followed by urine and sputum. All isolates showed multidrug resistance, and 84.2 % were XDR. This highlights the need for strict infection control measures, antibiotic stewardship, and alternative therapeutic strategies, particularly in burn units and surgical wards.

DECLARATIONS

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Ethical approval

The Ethics Committee of the College of Education for Pure Sciences, University of Diyala, Iraq, approved this study (approval no. :02).

Use of Artificial intelligence/Large language models

We also declare that we did not use Generative artificial intelligence (AI) and AI-assisted technologies in writing the manuscript.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

No conflict of interest is associated with this work.

Contribution of authors

We declare that this work was done by the author(s) named in this article, and all liabilities

pertaining to claims relating to the content of this article will be borne by the authors.

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