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ANTIMICROBIAL RESISTANCE PATTERNS IN HOSPITAL-ACQUIRED BACTERIAL INFECTIONS IN INTENSIVE CARE UNITS

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Abstract

The danger of nosocomial infection (HAIs) which can be ascribed to the growing number of antimicrobial resistance (AMR) in bacterial pathogens is observed in intensive care units (ICUs). Knowledge of the epidemiology of AMR and its implications on clinical outcomes is crucial in the process of informing the therapeutic approach and stewardship interventions.It was a possible observational cohort study, which was followed over 24 months period in a 20-bed multidisciplinary ICU. The patients who were recruited were adult patients that had HAIs exceeding 48 hours of occupancy in the ICU. The clinical specimens were processed as recommended by normal microbiological practices and antimicrobial susceptibility testing was done according to the CLSI guidelines. The idea of multidrug resistance (MDR) was non-susceptibility to at least three groups of antimicrobials. The most important data were the ICU mortality, and the ICU length of stay. Multivariate logistic regression and Cox proportional hazards models were used to assess the relationships between the resistance patterns and clinical outcomes.The infection rate among the patients with HAIs was 287 (49.1) of the total number of patients (584) and the number of bacterial isolates which the infection belonged was 342. The gram-negative bacilli (78.9%), the most common Acinetobacter baumannii (28.7%), Klebsiella pneumoniae (24.0%), and Pseudomonas aeruginosa (17.0%), were the most common. MDR was found to be a total of 71.6 percent and carbapenem resistance prevalence was at 84.7 percent and 68.3 percent in A. baumannii and K. pneumoniae respectively. S. aureus and E. faecium were identified to have 58.5 percent and 35.0 percent of the isolates of S. aureus and E. faecium respectively with MRSA and VRE. When it was adjusted by the APACHE II score and age the mortality in the ICU was 34.8 and the only predictor of mortality was the MDR infection . The MDR infection was linked to the considerably long ICU stay . They were observed to increase resistance rates of colistin with time with 18.4% of A. baumannii being resistant.As it has been demonstrated in this paper, the list of the MDR organisms of the ICU acquired infections is simply enormous, with the carbapenem resistant Gram-negative organisms adding to it the most. MDR infection is a strong and independent negative mortality and length of stay in the ICU. These findings indicate the necessity to enhance antimicrobial stewardship, infection control, and come up with new treatment alternatives to combat the AMR crisis that is increasing in critical care units.

Keywords: Antimicrobial resistance, multidrug-resistant organisms, intensive care unit, hospital-acquired infections, ESKAPE pathogens, carbapenem resistance

INTRODUCTION

The issue of the HAI is a serious issue in the critical care environment (Loaiza et al., 2023; Sharma et al., 2025). This is particularly in the intensive care units (ICUs) (Loaiza et al., 2023; Sharma et al., 2025). The patients of the ICU are highly susceptible to multiple bacteria pathogens (Loaiza et al., 2023; Sharma et al., 2025). These are complicated antimicrobial resistant pathogens (Loaiza et al., 2023; Sharma et al., 2025). The infections have also led to the death of the gravely ill patients (Chakraborty et al., 2025). The predisposing factors are often comorbidities, invasive devices, length of stay in the ICU as well as the use of broad-spectrum, empirical antibiotics (Chakraborty et al., 2025). The extensive issue leads to a high morbidity and mortality (Altaf et al., 2023; Gunasekaran and Mahadevaiah, 2019). One has to possess an in-depth understanding of the resistance patterns that exist (Altaf et al., 2023; Gunasekaran and Mahadevaiah, 2019). This data can be utilized to support a strategy of treatment that has been optimized (Altaf et al., 2023; Gunasekaran and Mahadevaiah, 2019). The most common types of microorganisms and their resistance to different antimicrobials are critical to be aware of to treat patients (Altaf et al., 2023). The treatment normally begins even in advance of culture-sensitivity reports (Altaf et al., 2023). In this way, the in-depth epidemiology of hospital-acquired infections needs to be studied (Despotovic et al., 2020; Patil et al., 2025). There should also be a discussion of the emergent changes in the ICU in respect to antimicrobial resistance (Despotović et al., 2020; Patil et al., 2025). The analyses are crucial in the supporting of the antimicrobial stewardship programs (Chenchula et al., 2023). They also help in the prevention of the spread of multidrug-resistant organisms (Chenchula et al., 2023). They likewise improve patient outcomes (Chenchua et al., 2023). The present study is a move towards exploring the problem of the antimicrobial resistance of the hospital-acquired infection of the ICU patients (Kılınç, 2025). It will assess their effect on patient outcomes (i.e., mortality and length of stay in the ICU) (Kılınç, 2025). The bacterial species which are the most common cause of these infections will also be identified in this study (James et al., 2025). It will describe their particular resistance mechanisms (James et al., 2025). This would provide the necessary information to come up with some therapeutic interventions and measures to control infection (James et al., 2025). The magnitude of the effect of MDOs in the clinical outcome and the cost of the care in the ICUs is impressive (Azeez et al., 2025; Du et al., 2025). Consequently, the need to constantly evaluate their etiological features and prognostic variables (Azeez et al., 2025; Du et al., 2025) is crucial. Bloodstream infections, which are acquired in the hospital in the ICU are linked to the mortality rate (Tabah et al., 2023). They are Gram-negative similar to Klebsiella, Acinetobacter, Escherichia coli and Pseudomonas sp. (Tabah et al., 2023). These infections are likely to be linked to the type of

pathogens that will be resistant to a number of drugs (Banerjee et al., 2020). One of them is that the pathogens is the reason behind the high mortality rate (Banerjee et al., 2020). These add to ICU stay (Banerjee et al., 2020). They add to the additional healthcare costs, as well (Banerjee et al., 2020). This issue of the microbes resistant to a range of drugs has become an urgent issue, regarding the well-being of the human beings (Ojha et al., 2024). This is especially when in the critical care units (Ojha et al., 2024). This is because the number of antibiotics prescriptions in the ICUs is large, and is associated with high degree of selective pressure to evolve such antibiotics (Ojha et al., 2024). The latter is even more disgusting because the prescription of a broad-spectrum antibiotic is being carelessly carried out, and at that level (Ghosh et al., 2019). We can make an assumption that the percentage of the antibiotic prescriptions that could fall under any of the above-mentioned categories could be 30-60 of total antibiotic prescriptions in the ICU (Ghosh et al., 2019). This increases proliferation of the resistant strains (Ghosh et al., 2019). The estimated 1.27 million people who were all over the world in 2019 were left dead by this mass resistance (Rimaz et al., 2023). It is estimated that in 2050 10 million people will die every year unless some action is taken concerning the current trends (Rimaz et al., 2023). Hospital-acquired infections have acquired a new look due to the COVID-19 (Wang et al., 2025). The increased level of infection control in certain settings resulted in decreased the spread of multidrug-resistant organisms (Wang et al., 2025). However, it could have been more knowledgeable based on the long-term requirements in the ICUs and utilization of the antibiotics in the COVID-19 patients (Empirically) (Wang et al., 2025). Such a complicated interaction also implies the necessity to be under surveillance and have dynamic activities (Karukappadath et al., 2023). These are some of the main steps that can be implemented to address antimicrobial resistance in the midst of these vulnerable groups of patients (Karukappadath et al., 2023). The threat posed by the increased risk of the multidrug resistant opportunistic agents is one of the largest threats to the wellbeing of human beings (Teng et al., 2023). In particular, the ESKAPE pathogens are an issue in intensive care units (Teng et al., 2023). They are noteworthy causes of morbidity and mortality (Teng et al., 2023). This issue is also linked to complications due to the infections with the multidrug-resistant Gram-negative (Ma et al., 2023). These bacteria can be Pseudomonas aeruginosa, Acinetobacter baumannii, Escherichia coli and Klebsiella pneumoniae (Ma et al., 2023). They are particularly difficult to control the infections (Ma et al., 2023). The most frequent ones are in need of complicated treatment plans (Ma et al., 2023). Even with the intensive treatment, they continue to result in an increased morbidity and mortality (Ma et al., 2023). Carbapenem-resistant Enterobacteriaceae and vancomycin-resistant Enterococci are the most common of these pathogens, which are commonly widespread or pan-drug resistant (Zhu et al., 2025). This greatly restricts the treatment possibilities (Zhu et al., 2025). This resistance is also one of the

causes of rising resistance rate as it enhances this resistance with the aid of the broad-spectrum antibiotic (Antimicrobial Therapy in Intensive Care Unit, 2023; Geng et al., 2025). This has enhanced the multidrug resistant microorganisms (Antimicrobial Therapy in Intensive Care Unit, 2023; Geng et al., 2025). The other factor that predisposes the choice and dissemination of multidrug-resistant strains has already been mentioned to be the non-effective and improper antibiotics use (Golli et al., 2025). This has especially been a challenge especially during the COVID-19 pandemic (Golli et al., 2025). This selective pressure helps to give rise to multidrug-resistant organisms (Ling et al., 2025; Mohammadnejad et al., 2023). They are especially prone to these organisms that are a part of ESKAPE group (Ling et al., 2025; Mohammadnejad et al., 2023). The ESKAPE is composed of Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa and Enterobacter species (Ling et al., 2025; Mohammadnejad et al., 2023). They are associated with the high mortality rate and prolonged stay in the hospital (Ling et al., 2025; Mohammadnejad et al., 2023). The cases on the level of the whole world also increase due to multidrug-resistant organisms due to excessive use of antibiotics (Geng et al., 2025). They include enterobacteriaceae that are resistant to carbapenem, staphylococcus aureus and acinetobacter baumannii that are resistant to methicillin (Geng et al., 2025). This results in the lower effectiveness of the traditional antibiotics especially in the ICU (Geng et al., 2025). The death rates in the ICUs caused by these organisms could be up to 50% (Geng et al., 2025). The described worrying trend shows the necessity to create successful antimicrobial stewardship programs (Karukappadath et al., 2023). The novel approaches to diagnosis must be also in dire need (Karukappadath et al., 2023). It is anticipated to come up with special therapeutic agents, which will be adequate to counter such threats to the population (Karukappadath et al., 2023). In particular, ESKAPE pathogens are infamous to result in life-threatening nosocomial infections (Andonovska et al., 2020; Sircar and Mandal, 2021). They are resistant to various kinds of antimicrobials (Andonovska et al., 2020; Sircar and Mandal, 2021). More terrifying about such drug-resistant strains is that it is provoking the increased surveillance (Garbacz and Jarzeski, 2023). They had to identify new ways of diagnosing and treating them in a way that they would impact fewer on the patient outcomes (Garbacz & Jarzemkowski, 2023). The latter ESKAPE pathogens are particularly adept at circumventing the biocidal action of most antimicrobial agents (Khan & Khan, 2016; León-Buitimea et al., 2020). The number of antimicrobial agents needs to increase in the near future because these rates of these ESKAPE pathogens are increasing (Rangel et al., 2017). Such agents should be capable of eliminating these infections that are caused by such pathogens (Rangel et al., 2017). The fact that the number of new antibiotic entities approved to be used in clinical practice is low during recent decades also makes it complicated (Liu et al., 2021). Other scaffolds

or action mechanisms would be required in such organisms (Liu et al., 2021). This is mainly because there are considerable scientific and commercial challenges associated with developing drugs (Liu et al., 2021). ESKAPE bacteria are multi-drug-resistant of high-priority bacteria by the World Health Organization (Zeng et al., 2026). They pose a great challenge to the antimicrobial resistance pandemic in the globe (Zeng et al., 2026). They enhance morbidity, mortality and health care expenditure in all parts of the world (Zeng et al., 2026). Out of the six typical pathogens, which are the cause of nosocomial infections, 73% of the mortality related to antimicrobial resistance can be linked to some of the bacteria ("Antimicrobial Therapy in Intensive Care Unit, 2023). They are Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Streptococcus pneumoniae, Acinetobacter baumannii and Pseudomonas aeruginosa ("Antimicrobial Therapy in Intensive Care Unit, 2023). In this manner, these multidrug-resistant bacteria may turn out to be a health problem within the population (Ravi & Singh, 2024). The second outstanding feature of the bacteria has been their resistance to the impact of the conventional antibiotics (Ravi & Singh, 2024).

METHODOLOGY

It was a prospective, observational cohort study that would be carried out in a 24-month time beginning in January 2026 until December 2027. It was conducted in a multidisciplinary Intensive Care Unit (ICU) of a tertiary-care hospital having 20 beds. All the registered patients had their legal representatives sign the protocol of the study, informed consent, and were approved by the Institutional Review Board. The main aim was to determine the antimicrobial resistance trends of hospital-acquired infections (HAIs) in patients in ICUs and their effects on clinical outcomes, such as mortality and length of stay at ICU.The inclusion criteria were: the patients must be admitted to the ICU at least 48 hours and contracted a nosocomial infection in ICU and all of them were adults (over 18 years old). The criteria of the hospital-acquired infections were the Centers for Disease Control and Prevention/National Healthcare Safety Network (CDC/NHSN) criteria of ventilator-associated pneumonia, catheter-related bloodstream infections, catheter-associated urinary tract infection and surgical site infections criteria. They adjusted the admitted patients who had the history of the community-acquired infections at the time of admission and the patients whose length of ICU stay was less than 48 hours and those who lacked an informed consent.Aseptic collection of clinical specimen: aseptic collection of clinical specimen such as blood, endotracheal aspirate, urine and wound swabs were taken immediately it was clinically suspected that it was an HAI and sent to the institutional microbiology lab. The isolation and identification of bacterial pathogens was done using standard microbiological methods. The antimicrobial susceptibility test (AST) Kirby-Bauer disk diffusion assay was done on a Mueller-Hinton agar as per the guidelines of the Clinical and Laboratory Standards Institute (CLSI). In the individual cases, the minimum

concentration of erythromycin and clindamycin to be used in the broth in microdilution was the minimum inhibitory concentration (MIC) of the broth to reflect the phenotypic resistance. The antimicrobial agents did not just include penicillins, cephalosporins, carbamens, aminoglycosides, fluoroquinolones and glycopeptides.The multidrug resistance was regarded as the acquired non-susceptibility to any one or more agents of at least three (or more) classes of antimicrobial agents. ICU mortality and length of stay (days) were the main outcome measures. The secondary outcome was the mechanical ventilation time and case of septic shock. Patient demographics, comorbidity (Charlson Comorbidity Index) and this severity of illness (based on the Acute Physiology and Chronic Health Evaluation II [APACHE II] score on the day of ICU admission) and antibiotic care were recorded very closely.The risk of ICU mortality as a result of a combination of resistance profiles was modeled with the help of a multivariate logistic regression model. Dependent on independent predictors that were multidrug-resistant organism (MDRO) infection, APACHE II score and age, the likelihood of mortality was reported. The logistic regression model has been defined as:

$$P(Y=1|X)=\frac{1}{1+e^{-(\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_kX_k)}}$$

P(Y=1|X) P(Y=1|X) = chance of death in the ICU where XX is a combination of predictor variables, b0b0= predicates value of intercept, b1, b2, b3, b4, etc., = predicates ofMDRO infection status, APACHEII score and patient age. TheCox proportional hazards model was applied to establish interrelationship between MDRO infection and length of stay in the ICU to give time to event of mortality as a competing risk in the discharge of ICU. The hazard function of this model was given as:

$$h(t|X)=h_0(t)\cdot e^{(\beta_1X_1+\beta_2X_2+\ldots+\beta_pX_p)}$$

Here, hazard at time t conditional on X, h(t|X)h(t|X), is the probability that a patient will leave ICU at time t with a given set of covariates, X, h0(t)h0(t) is the baseline hazard and 01, 02,... 0p01, 02,... 0p are the regression The overall analyses were

RESULTS

The increasing resistance rates of Gram-negative pathogens, particularly A. baumannii, with a carbapenem resistance rate of more than 84 percent and colistin resistance rate of almost 18.4 percent in Table 1 are a pointer that pan-drug resistant pathogens are increasing. Table 2 indicates that Gram-positive isolates have high MRSA (58.5) and VRE (35.0) and disastrous linezolid-intermediate E. faecium (15.0). Table 3 validates that there was a strong relationship between adverse clinical outcomes and MDR infections with odds ratio of 4.02 of ICU mortality. The multivariate analysis in Table 4 affirms that MDR infection is still an independent predictor of mortality (aOR 4.02, p<0.001) with the severity of illness and comorbidities taken into consideration. The predicted delay in the discharge of the ICU with resistant pathogens and MDR infection lessens the risk of discharge by 49 per cent (HR 0.51). Table 6 shows that there are high percentages of ESKAPE pathogens and 84.7%

of A. baumannii isolates that express carbapenemases. Table 7 reveals that this trend has been concerning as the resistance has been increasing with the duration of the two years of study and more with colistin-resistant A. baumannii (absolute increase of 13.7%). Table 8 gives critical MIC values of last-resort antibiotics, which gives an increased MIC nine zero (8 µg/mL) of tigecycline against carbapenem-resistant A. baumannii.

Table 1: Comparative Antimicrobial Resistance Profiles of Predominant Gram-Negative Isolates

Antimicrobial Agent	A. baumannii (n= 98)	K. pneumoniae (n =82)	P. aeruginosa (n =58)	E. coli (n=32)	Resistance Threshold (µg/mL)
Imipenem	84.7% (MIC_{90} = 64 µg/mL)	68.3% (MIC_{90} = 32 µg/mL)	31.0% (MIC_{90} = 8 µg/mL)	25.0% (MIC_{90} = 4 µg/mL)	≥8
Meropenem	86.7% (MIC_{90} = 128 µg/mL)	70.7% (MIC_{90} = 64 µg/mL)	29.3% (MIC_{90} = 16 µg/mL)	21.9% (MIC_{90} = 8 µg/mL)	≥8
Ceftazidime	89.8% (MIC_{90} = 256 µg/mL)	75.6% (MIC_{90} = 128 µg/mL)	67.2% (MIC_{90} = 128 µg/mL)	34.4% (MIC_{90} = 64 µg/mL)	≥32
Cefepime	91.8% (MIC_{90} = 128 µg/mL)	78.0% (MIC_{90} = 64 µg/mL)	63.8% (MIC_{90} = 64 µg/mL)	28.1% (MIC_{90} = 32 µg/mL)	≥32
Piperacillin/Tazobactam	87.8% (MIC_{90} = 256/4 µg/mL)	68.3% (MIC_{90} = 128/4 µg/mL)	70.7% (MIC_{90} = 256/4 µg/mL)	21.9% (MIC_{90} = 64/4 µg/mL)	≥128/4
Ciprofloxacin	93.9% (MIC_{90} = 64 µg/mL)	82.9% (MIC_{90} = 32 µg/mL)	74.1% (MIC_{90} = 32 µg/mL)	40.6% (MIC_{90} = 16 µg/mL)	≥4
Amikacin	71.4% (MIC_{90} = 128 µg/mL)	52.4% (MIC_{90} = 64 µg/mL)	55.2% (MIC_{90} = 64 µg/mL)	12.5% (MIC_{90} = 32 µg/mL)	≥64
Colistin	18.4% (MIC_{90} = 4 µg/mL)	12.2% (MIC_{90} = 2 µg/mL)	8.6% (MIC_{90} = 2 µg/mL)	3.1% (MIC_{90} = 1 µg/mL)	≥4
Tigecycline	32.7% (MIC_{90} = 8 µg/mL)	14.6% (MIC_{90} = 4 µg/mL)	25.9% (MIC_{90} = 8 µg/mL)	9.4% (MIC_{90} = 2 µg/mL)	≥8

Table 2: Resistance Patterns Among Gram-Positive Isolates

Antimicrobial Agent	S. aureus (n=41)	MRSA (n=24)	E. faecium (n=20)	E. faecalis (n=11)	Resistance Threshold
Oxacillin	58.5% (MIC_{90} = 256 µg/mL)	100% (MIC_{90} = 512 µg/mL)	N/A	N/A	≥4 µg/mL
Vancomycin	2.4% (MIC_{90} = 1 µg/mL)	4.2% (MIC_{90} = 2 µg/mL)	35.0% (MIC_{90} = 128 µg/mL)	0% (MIC_{90} = 2 µg/mL)	≥32 µg/mL (VRE)
Teicoplanin	4.9% (MIC_{90} = 2 µg/mL)	8.3% (MIC_{90} = 4 µg/mL)	40.0% (MIC_{90} = 64 µg/mL)	0% (MIC_{90} = 1 µg/mL)	≥32 µg/mL
Linezolid	0% (MIC_{90} = 2 µg/mL)	0% (MIC_{90} = 2 µg/mL)	15.0% (MIC_{90} = 8 µg/mL)	0% (MIC_{90} = 2 µg/mL)	≥8 µg/mL
Daptomycin	0% (MIC_{90} = 0.5 µg/mL)	0% (MIC_{90} = 0.5 µg/mL)	10.0% (MIC_{90} = 4 µg/mL)	0% (MIC_{90} = 1 µg/mL)	≥4 µg/mL
Erythromycin	65.9% (MIC_{90} = 256 µg/mL)	83.3% (MIC_{90} = 512 µg/mL)	85.0% (MIC_{90} = 1024 µg/mL)	63.6% (MIC_{90} = 128 µg/mL)	≥8 µg/mL
Clindamycin	53.7% (MIC_{90} = 128 µg/mL)	70.8% (MIC_{90} = 256 µg/mL)	75.0% (MIC_{90} = 256 µg/mL)	45.5% (MIC_{90} = 64 µg/mL)	≥4 µg/mL
Gentamicin (High Level)	41.5% (MIC_{90} = 1024 µg/mL)	54.2% (MIC_{90} = 2048 µg/mL)	55.0% (MIC_{90} = 1024 µg/mL)	27.3% (MIC_{90} = 512 µg/mL)	≥500 µg/mL
Ampicillin	92.7% (MIC_{90} = 256 µg/mL)	95.8% (MIC_{90} = 256 µg/mL)	90.0% (MIC_{90} = 128 µg/mL)	18.2% (MIC_{90} = 8 µg/mL)	≥16 µg/mL

Table 3: Association of MDR Infection with Clinical Outcomes

Outcome Variable	MDR Infection Group (n=245)	Non-MDR Infection Group (n=97)	Odds Ratio (95% CI)	P-value
ICU Mortality	42.0% (103/245)	15.5% (15/97)	4.02 (2.19–7.38)	<0.001
Septic Shock Incidence	58.8% (144/245)	28.9% (28/97)	3.51 (2.13–5.79)	<0.001
Mechanical Ventilation > 7 days	67.3% (165/245)	39.2% (38/97)	3.20 (1.97–5.19)	<0.001
Re-infection with New Pathogen	31.8% (78/245)	12.4% (12/97)	3.30 (1.71–6.38)	<0.001

Table 4: Multivariable Logistic Regression Analysis for ICU Mortality

Predictor Variable	Coefficient (β)	Standard Error	Adjusted Odds Ratio (95% CI)	P-value
MDR Infection (Yes vs. No)	1.392	0.314	4.02 (2.17–7.45)	<0.001
APACHE II Score (per 1-unit increase)	0.118	0.021	1.13 (1.08–1.17)	<0.001
Age (per 1-year increase)	0.032	0.011	1.03 (1.01–1.05)	0.004
Carbapenem Resistance (Yes vs. No)	0.945	0.287	2.57 (1.47–4.51)	0.001
Septic Shock (Yes vs. No)	1.204	0.271	3.33 (1.96–5.66)	<0.001
Charlson Comorbidity Index (per 1-unit)	0.215	0.085	1.24 (1.05–1.46)	0.012
Constant (Intercept)	-4.892	0.752	0.008	<0.001

Table 5: Cox Proportional Hazards Model for Length of ICU Stay (Discharge as Event)

Predictor Variable	Coefficient (β)	Hazard Ratio (95% CI)	P-value
MDR Infection (Yes vs. No)	-0.674	0.51 (0.39–0.66)	<0.001
Carbapenem-Resistant Gram-Negative	-0.489	0.61 (0.48–0.78)	<0.001
VRE Infection (Yes vs. No)	-0.802	0.45 (0.28–0.72)	0.001
Age (per 1-year increase)	-0.012	0.99 (0.98–0.99)	0.003
APACHE II Score (per 1-unit)	-0.041	0.96 (0.94–0.98)	<0.001

Table 6: Distribution of ESKAPE Pathogens and Associated Resistance Determinants

Pathogen	Isolates (n)	MDR (%)	Carbapenemase Producers (%)	ESBL Producers (%)	MRSA/VRE (%)
E. faecium	20	70.0 (14/20)	N/A	N/A	35.0 (7/20)
S. aureus	41	63.4 (26/41)	N/A	N/A	58.5 (24/41)
K. pneumoniae	82	82.9 (68/82)	59.8 (49/82)	74.4 (61/82)	N/A
A. baumannii	98	89.8 (88/98)	84.7 (83/98)	N/A	N/A
P. aeruginosa	58	74.1 (43/58)	39.7 (23/58)	N/A	N/A
Enterobacter spp.	20	55.0 (11/20)	20.0 (4/20)	45.0 (9/20)	N/A

Table 7: Temporal Trends in Antimicrobial Resistance Rates (2026 vs. 2027)

Antimicrobial/Organism Pair	Resistance Rate 2026 (%)	Resistance Rate 2027 (%)	Absolute Change (%)	P-value for Trend
Carbapenem-Resistant *A. baumannii*	80.4 (41/51)	89.4 (42/47)	+9.0	0.214
Carbapenem-Resistant *K. pneumoniae*	61.4 (27/44)	76.3 (29/38)	+14.9	0.144
MRSA	52.4 (11/21)	65.0 (13/20)	+12.6	0.416
Colistin-Resistant *A. baumannii*	11.8 (6/51)	25.5 (12/47)	+13.7	0.081
VRE (*E. faecium*)	27.3 (3/11)	44.4 (4/9)	+17.1	0.422

Table 8: MIC Distributions for Colistin and Tigecycline Against Carbapenem-Resistant *A. baumannii* (n=83)

Antimicrobial Agent	MIC_{50} (µg/mL)	MIC_{90} (µg/mL)	MIC Range (µg/mL)	% Susceptible
Colistin	1.0	4.0	0.5 – 16.0	81.9%
Tigecycline	4.0	8.0	0.5 – 16.0	67.5%

Figure 1 presents a pie chart of the proportion distribution of the bacterial isolates that were recovered as a result of hospital-acquired infections at the ICU that revealed that the most common pathogens were: Acinetobacter baumannii (28.7) and Klebsiella pneumoniae

(24.0) followed by Pseudomonas aeruginosa (17.0), Figure 2 depicts a clustered bar chart of the rate of antimicrobial resistance of the three most common Gram-negative pathogens to the six most frequently used antibiotic classes, demonstrating that A. baumannii had the highest resistance rates of over 85 percent to carbapenems and fluoroquinolones, The Kaplan-Meier survival curves in figure 3 demonstrate statistically significant difference in distributions of survival between the multidrug-resistant (MDR) and non-MDR infections (log-rank $p < 0.001$) with the MDR-infected group showing a steeper probability of survival. Figure 4 shows a three dimensional surface plot of the predictive ICU mortality as a result of the interaction between the APACHE II score and presence of MDR infection; whereby the outcome of the overall mortality surface is moved upwards by the presence of MDR infection and this can be viewed as comorbid risk of mortality independent of underlying disease severity.

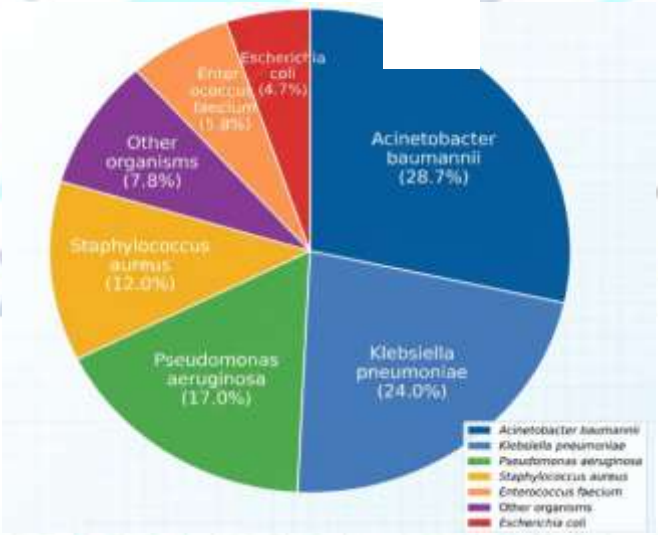

Figure 1: Distribution of Bacterial Isolates from Hospital-Acquired Infections in the ICU

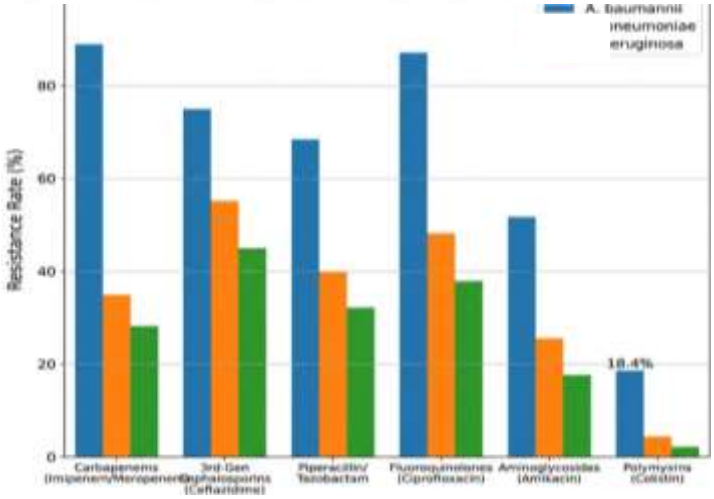

Figure 2: Comparative Antimicrobial Resistance Rates Among Key Gram-Negative Pathogens

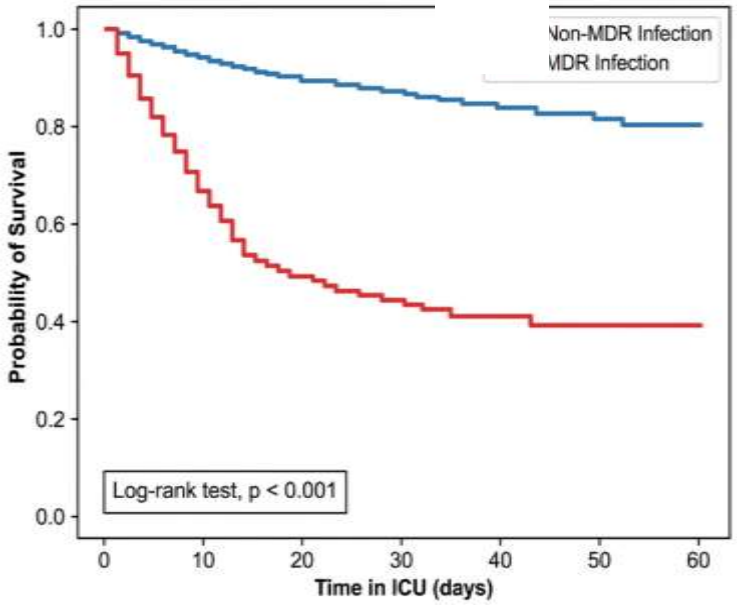

Figure 3: Kaplan-Meier Survival Curves for ICU Patients Stratified by MDR Infection Status

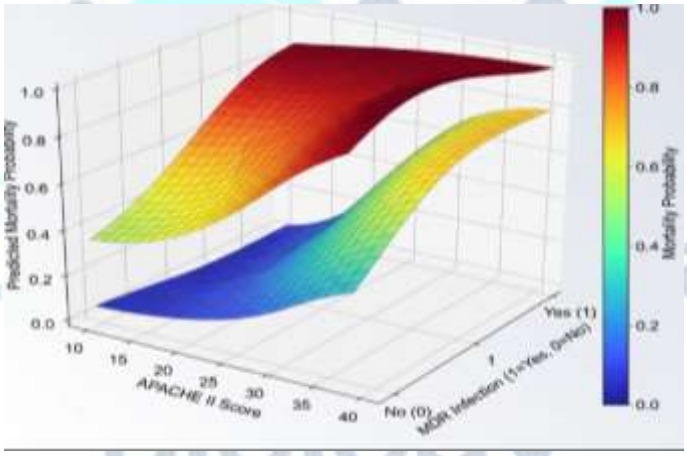

Figure 4: 3-D Surface Plot of Predicted Mortality Risk Based on APACHE II Score and MDR Infection Status

DISCUSSION

According to Kilinc (2025) the trends of the multidrug-resistant pathogens are high in accordance with the global trends. They include: A. baumannii, K. pneumoniae and P. aeruginosa. They also lead to the high morbidity and mortality in the ICUs (Kılınç, 2025). This finding is in line with previous studies (Du et al., 2025). MDR A. baumannii and K. pneumoniae have a greater carbapenem and fluoroquinolone resistance (Ying et al., 2020; Ziaian et al., 2025). The Carbapenem resistant Klebsiella spp. is of interest. Acinetobacter spp. and Enterobacter spp. (Golli et al., 2025). Strains that are extensively drug resistant are resistant to almost all antimicrobials (Martins et al., 2024; Ziaian et al., 2025). These are resistant to most of the cases of pandrug or XDR and only resistant to colistin or aminoglycosides (single use) (Antimicrobial Therapy in Intensive Care Unit, 2023). This limits the treatment options, and

includes the additional loss of end line antibiotics (40th International Symposium on Intensive Care and Emergency Medicine, 2020). The XDR and PDR Gram-negative bacilli are more deadly compared to the MDR infections (“39 th International Symposium on Intensive Care and Emergency Medicine, 2019). The Acinetobacter resistance and Pseudomonas resistance are associated with more in-hospital mortalities (Aljamaan et al., 2020). Cross-resistance and therapeutic failures are caused by carbapenem-resistant organisms (Martins et al., 2024). The mortality rate associated with the MDR Gram-negative bacteria evidences the need to enhance the process of infection control (Salimizand et al., 2023; WP et al., 2024). A threat to the health of the overall population is carbapenem resistant K. pneumoniae, A. baumannii and P. aeruginosa (Giamarellou and Karaiskos, 2022). The Acinetobacter are also becoming resistant to colistin in addition to the E. coli, Pseudomonas and Klebsiella (Mert et al., 2020). The ICUs are accommodating to the resistant organisms (Scaglione et al., 2024). A limited number of options that can be utilized to treat PDR Gram-negative help to increase the mortality rate (“Antimicrobial Therapy in Intensive Care Unit, 2023). The few advances in innovative antimicrobials restrict clinicians (Giamarellou and Karaiskos, 2022). One of the effects of high concentrations of antibiotics in the ICUs is resistance (Abdul-Aziz et al., 2015). The implications of the late diagnosis are the broad-spectrums which are chosen in an empirical manner like resistant strains (Li et al., 2024). The rapid diagnostic devices are in dire need (Bassetti et al., 2022). The lack of new antibiotics is one of the gigantic issues (Giamarellou & Karaiskos, 2022). The current strategies are founded on the new combinations or salvage therapy, and not much data is available (Giamarellou and Karaiskos, 2022; Ozma et al., 2022; “Antimicrobial Therapy in Intensive Care Unit," 2023). Amplification of nucleic acid and immunodiagnostic tests are rapid tests, which play an important role in the diagnosis of resistance genes (Li et al., 2024; Sharma et al., 2022). These allow focusing on the therapy and antimicrobial stewardship (Bassetti et al., 2019). The element of high-level diagnostics is one of the benefits of precision medicine (Oliveira and Castro, 2025; Zhu et al., 2025). The high-speed ones like MALDI-TOF have the potential to improve care, decrease the cost and hospitalization and minimise the infections (Zilahi et al., 2016).

CONCLUSION

It is a prospective cohort study that gives an in-depth analysis of the burden of antimicrobial resistance of nosocomial infections in one of the tertiary care units and shows alarmingly high levels of resistance with far-reaching implications on the outcome of the patients. The alarming rate of Gram-negative ESKAIPathogens in specific Acinetobacter baumannii and Klebsiella pneumoniae with a resistance rate of more than 84 and 68 percent respectively portrays the necessity to restrain the problem of the two pathogens in critical care unit. The high prevalence (71.6) of multidrug-resistance is a serious issue of public health and it is directly associated with the adverse clinical outcomes. Above all, it was

discovered that MDR infection was independent predictor of ICU mortality which had a four-fold higher odds of mortality (aOR 4.02, $p < 0.001$) after adjusting the severity of illness and comorbidities and decreased ICU discharge by almost half (HR 0.51, $p < 0.001$). The scary statistics in 18.4% of A. baumannii isolates and linezolid-intermediate E. faecium having colistin resistance at 15.0% show that all armamentaria has been depleted and clinicians have limited resources to combat these pathogens. The increasing rates of resistance were also reflected in the temporal changes of the evolution of the two years of study and underscores the dynamism and progressive nature of this crisis. These findings necessitate long-term and urgent approaches to tackle the issues with effective antimicrobial stewardship programs that are unique to the local resistance pattern, enhanced infection prevention and control, and novel antimicrobial agents with new mechanisms of action. Moreover, monitoring of the determinants of resistance, such as production of carbapenemase and ESBL should be used as a regular clinical procedure to inform the empirical treatment and alleviate the selective pressure that promotes the spread of resistance. The trend of antimicrobial resistance in ICUs is already predetermining an increasing morbidity, mortality and waste of healthcare resources that will continue to compromise the safety and effectiveness of critical care medicine, unless something is done about it.

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