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Original Article

Superbugs in the ICU: Unmasking Multidrug-Resistant Infections

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ABSTRACT

Introduction: Multidrug-resistant (MDR) infections have emerged as a major challenge in intensive care units (ICUs), contributing to increased morbidity, mortality, prolonged hospitalization, and escalating healthcare costs. The widespread use of invasive devices and broad-spectrum antibiotics has accelerated the emergence of resistant pathogens, necessitating continuous surveillance of local resistance patterns and associated risk factors.

Materials and Methods: A hospital-based observational cross-sectional study was conducted among 120 adult ICU patients with culture-confirmed bacterial infections between January 2025 and December 2025. Demographic characteristics, comorbidities, clinical risk factors, microbiological findings, antimicrobial susceptibility patterns, and patient outcomes were recorded using a structured case record form. Bacterial identification and antimicrobial susceptibility testing were performed according to standard microbiological procedures and interpreted using the latest Clinical and Laboratory Standards Institute (CLSI) guidelines. Multidrug resistance was defined according to internationally accepted criteria. Statistical analysis was performed using SPSS version 26.0, with a p-value <0.05 considered statistically significant.

Results: The mean age of patients was predominantly between 46 and 60 years, and 61.7% were males. Overall, **67.5%** of isolates were multidrug resistant. *Acinetobacter baumannii* (25.8%) and *Klebsiella pneumoniae* (23.3%) were the most frequently isolated organisms. Ventilator-associated pneumonia (31.7%) was the leading source of infection. High resistance was observed against ampicillin (86.7%), ceftriaxone (76.7%), and ceftazidime (72.5%), whereas colistin (94.2%) and tigecycline (89.2%) demonstrated the highest susceptibility. Prior antibiotic exposure, mechanical ventilation, prolonged ICU stay, central venous catheterization, and diabetes mellitus were independent predictors of MDR infection. Patients with MDR infections experienced significantly longer ICU stay, prolonged mechanical ventilation, and higher ICU mortality than those with non-MDR infections ($p<0.05$).

Conclusion: Multidrug-resistant bacterial infections are highly prevalent among ICU patients and are associated with adverse clinical outcomes. Continuous microbiological surveillance, early identification of resistant pathogens, rational antibiotic prescribing, effective antimicrobial stewardship, and strict infection prevention practices are essential to reduce the burden of MDR infections and improve patient outcomes in critical care settings.

Keywords: *Multidrug-resistant organisms; Intensive care unit; Antimicrobial resistance; Healthcare-associated infections; Acinetobacter baumannii.*

INTRODUCTION

Healthcare-associated infections remain one of the leading causes of morbidity and mortality among critically ill patients admitted to intensive care units (ICUs) [1]. The widespread use of invasive devices, prolonged hospitalization, immunocompromised status, and frequent exposure to broad-spectrum antibiotics create an ideal environment for the emergence and transmission of multidrug-resistant (MDR) pathogens [2]. These infections are associated with delayed clinical recovery, increased healthcare costs, prolonged ICU stay, and substantially higher mortality rates [3]. The World Health Organization (WHO) has recognized antimicrobial resistance (AMR) as one of the top global public health threats, emphasizing the urgent need for improved surveillance, antimicrobial stewardship, and infection prevention strategies [4].

The epidemiology of MDR organisms in ICUs has evolved considerably over the past decade, with Gram-negative bacilli such as *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Escherichia coli* emerging as the predominant pathogens in many healthcare settings [5]. The increasing prevalence of carbapenem-resistant Enterobacterales (CRE), carbapenem-resistant *Acinetobacter baumannii* (CRAB), carbapenem-resistant *Pseudomonas aeruginosa* (CRPA), methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) has significantly limited therapeutic options, often necessitating the use of last-resort agents such as colistin and tigecycline [6]. The emergence of these highly resistant organisms poses substantial challenges for clinicians, particularly in critically ill patients requiring timely and effective antimicrobial therapy [7].

Several patient- and healthcare-related factors contribute to the development of MDR infections in the ICU [8]. Advanced age, underlying comorbidities such as diabetes mellitus and chronic kidney disease, prior antibiotic exposure, prolonged hospitalization, mechanical ventilation, urinary catheterization, central venous catheterization, and repeated ICU admissions have consistently been identified as important risk factors [9]. Understanding the distribution of resistant pathogens, their antimicrobial susceptibility profiles, and the clinical determinants associated with MDR infections is essential for guiding empirical antibiotic selection, strengthening antimicrobial stewardship programs, and implementing targeted infection control measures [10]. However, resistance patterns vary considerably across institutions and geographical regions, underscoring the importance of local epidemiological surveillance.

In view of the growing burden of antimicrobial resistance in critical care settings and the need for institution-specific data, the present study aimed to determine the spectrum of bacterial pathogens causing ICU infections, assess the prevalence and antimicrobial resistance patterns of multidrug-resistant organisms, identify factors associated with MDR infections, and evaluate their impact on clinical outcomes among critically ill patients.

MATERIALS AND METHODS

This hospital-based observational cross-sectional study was conducted in the Intensive Care Unit (ICU) of a tertiary care teaching hospital over a period of 1 year, from January 2025 to December 2025. The study included 120 consecutive adult patients admitted to the ICU with clinically suspected infections and microbiologically confirmed bacterial isolates obtained from appropriate clinical specimens. Patients aged 18 years and above with positive bacterial cultures were enrolled, whereas those with fungal or viral infections, duplicate isolates from the same infectious episode, incomplete microbiological records, or contaminated specimens were excluded. Prior approval was obtained from the Institutional Ethics Committee before commencement of the study, and patient confidentiality was maintained throughout the study.

Demographic and clinical data were collected using a predesigned case record form. Information including age, sex, ICU type, underlying comorbidities, prior hospitalization, previous antibiotic exposure within the preceding 90 days, use of invasive devices such as mechanical ventilation, urinary catheters, and central venous catheters, duration of ICU stay, and occurrence of septic shock was recorded. Clinical outcomes including duration of mechanical ventilation, length of ICU stay, total hospital stay, development of acute kidney injury, discharge status, and ICU mortality were also documented.

Clinical specimens, including blood, urine, respiratory secretions, wound swabs, and other relevant samples, were collected under aseptic precautions and processed in the Department of Microbiology according to standard laboratory protocols. Bacterial identification was performed using conventional microbiological techniques and automated identification systems wherever available. Antimicrobial susceptibility testing was carried out using the Kirby–Bauer disc diffusion method and interpreted according to the latest Clinical and Laboratory Standards Institute (CLSI) guidelines. Multidrug-resistant (MDR), extensively drug-resistant (XDR), and pandrug-resistant (PDR) organisms were classified based on internationally accepted criteria proposed by Magiorakos et al., with MDR defined as acquired non-susceptibility to at least one agent in three or more antimicrobial classes.

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software version 20 (IBM Corp., Armonk, NY, USA). Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as mean ± standard deviation. Associations between categorical variables were evaluated using the Chi-square test or Fisher's exact test, as appropriate, whereas continuous variables were compared using the independent samples t-test. Variables demonstrating statistical significance on univariate analysis were entered into a multivariable logistic regression model to identify independent predictors of multidrug-resistant infections. Adjusted

odds ratios (ORs) with 95% confidence intervals (CIs) were calculated, and a p-value <0.05 was considered statistically significant.

RESULTS

A total of 120 ICU patients with culture-confirmed bacterial infections were included in the study. The largest proportion of patients belonged to the 46–60 years age group (31.7%), followed by those aged >60 years (28.3%). Males constituted 61.7% of the study population. Medical ICU admissions accounted for 43.3% of cases, while diabetes mellitus (40.0%) and hypertension (36.7%) were the most common comorbidities. Chronic kidney disease, COPD, malignancy, and immunosuppression were present in smaller proportions of patients (Table 1).

Table 1. Baseline Characteristics of the Study Population (N = 120)

Variable	Category	n (%)
Age (years)	18–30	18 (15.0)
	31–45	30 (25.0)
	46–60	38 (31.7)
	>60	34 (28.3)
Gender	Male	74 (61.7)
	Female	46 (38.3)
ICU Type	Medical ICU	52 (43.3)
	Surgical ICU	42 (35.0)
	Trauma ICU	26 (21.7)
Diabetes mellitus	Yes	48 (40.0)
Hypertension	Yes	44 (36.7)
Chronic kidney disease	Yes	18 (15.0)
COPD	Yes	16 (13.3)
Malignancy	Yes	11 (9.2)
Immunosuppression	Yes	14 (11.7)

Mechanical ventilation was required in 65.0% of patients, while urinary and central venous catheters were used in 80.0% and 57.5% of patients, respectively. Nearly seven out of ten patients (69.2%) had received antibiotics within the preceding 90 days, and more than half (55.8%) had a history of previous hospitalization. Approximately half of the patients experienced an ICU stay exceeding seven days, and septic shock was present in 30.8% of cases (Table 2).

Table 2. Clinical Characteristics of ICU Patients

Variable	Category	n (%)
Mechanical ventilation	Yes	78 (65.0)
Central venous catheter	Yes	69 (57.5)
Urinary catheter	Yes	96 (80.0)
Prior antibiotic exposure (≤90 days)	Yes	83 (69.2)
Previous hospitalization	Yes	67 (55.8)
Previous ICU admission	Yes	32 (26.7)
ICU stay >7 days	Yes	59 (49.2)
Septic shock at admission	Yes	37 (30.8)

Ventilator-associated pneumonia was the predominant source of infection, accounting for 31.7% of cases. Bloodstream infections (20.0%) and catheter-associated urinary tract infections (18.3%) were the next most frequent sources, followed by surgical site infections (12.5%) and intra-abdominal infections (9.2%). Skin and soft tissue infections and other sources together comprised less than 10% of all infections (Table 3).

Table 3. Source of Infection

Infection Source	n (%)
Ventilator-associated pneumonia	38 (31.7)
Bloodstream infection	24 (20.0)
Catheter-associated UTI	22 (18.3)
Surgical site infection	15 (12.5)
Intra-abdominal infection	11 (9.2)
Skin & soft tissue infection	6 (5.0)
Others	4 (3.3)

Among the bacterial isolates, *Acinetobacter baumannii* was the most frequently isolated organism (25.8%), followed by *Klebsiella pneumoniae* (23.3%) and *Escherichia coli* (17.5%). *Pseudomonas aeruginosa* accounted for 15.0% of isolates, whereas *Staphylococcus aureus* and *Enterococcus* species represented 10.0% and 5.0% of isolates, respectively (Table 4).

Table 4. Bacterial Isolates Identified

Organism	**n (%)**
Acinetobacter baumannii	31 (25.8)
Klebsiella pneumoniae	28 (23.3)
Escherichia coli	21 (17.5)
Pseudomonas aeruginosa	18 (15.0)
Staphylococcus aureus	12 (10.0)
Enterococcus spp.	6 (5.0)
Others	4 (3.3)

Overall, multidrug-resistant (MDR) organisms constituted 67.5% of all isolates, while 32.5% were classified as non-MDR. *Acinetobacter baumannii* demonstrated the highest burden of MDR isolates, followed by *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. Methicillin-resistant *Staphylococcus aureus* and MDR *Enterococcus* species were identified less frequently (Table 5).

Table 5. Distribution of Multidrug-Resistant Organisms

Organism	**MDR**	**Non-MDR**	**Total**
Acinetobacter baumannii	25	6	31
Klebsiella pneumoniae	20	8	28
Escherichia coli	11	10	21
Pseudomonas aeruginosa	12	6	18
Staphylococcus aureus (MRSA)	8	4	12
Enterococcus spp.	3	3	6
Others	2	2	4
Total	**81 (67.5%)**	**39 (32.5%)**	**120**

High resistance rates were observed against commonly used antibiotics, particularly ampicillin (86.7%), ceftriaxone (76.7%), and ceftazidime (72.5%). Fluoroquinolones and gentamicin also demonstrated considerable resistance, while carbapenem resistance ranged from 38.3% to 40.8%. Resistance to colistin (5.8%) and tigecycline (10.8%) remained relatively low (Table 6).

Table 6. Antibiotic Resistance Pattern Among Isolates

Antibiotic	**Resistant n (%)**
Ampicillin	104 (86.7)
Ceftriaxone	92 (76.7)
Ceftazidime	87 (72.5)
Piperacillin-Tazobactam	58 (48.3)
Ciprofloxacin	74 (61.7)
Levofloxacin	68 (56.7)
Gentamicin	63 (52.5)
Amikacin	42 (35.0)
Meropenem	49 (40.8)
Imipenem	46 (38.3)
Colistin	7 (5.8)
Tigecycline	13 (10.8)

Colistin exhibited the highest antimicrobial susceptibility (94.2%), followed by tigecycline (89.2%). Amikacin and carbapenems retained moderate activity against bacterial isolates, whereas susceptibility to cephalosporins and ampicillin was markedly reduced, reflecting extensive antimicrobial resistance among ICU pathogens (Table 7).

Table 7. Antibiotic Susceptibility Pattern

Antibiotic	**Sensitive n (%)**
Colistin	113 (94.2)
Tigecycline	107 (89.2)
Amikacin	78 (65.0)
Imipenem	74 (61.7)
Meropenem	71 (59.2)

Piperacillin-Tazobactam	62 (51.7)
Gentamicin	57 (47.5)
Levofloxacin	52 (43.3)
Ciprofloxacin	46 (38.3)
Ceftazidime	33 (27.5)
Ceftriaxone	28 (23.3)
Ampicillin	16 (13.3)

Advanced age, diabetes mellitus, mechanical ventilation, central venous catheterization, urinary catheterization, prior antibiotic exposure, previous hospitalization, prolonged ICU stay, and septic shock were significantly associated with MDR infections. Male sex did not demonstrate a statistically significant association with MDR infection (Table 8).

Table 8. Factors Associated with MDR Infection

Variable	MDR (n=81)	Non-MDR (n=39)	χ^2	p value
Age >60 years	30	4	8.76	0.003
Male gender	53	21	0.68	0.408
Diabetes mellitus	39	9	5.09	0.024
Mechanical ventilation	61	17	12.46	<0.001
Central venous catheter	55	14	10.88	0.001
Urinary catheter	72	24	5.48	0.019
Prior antibiotic exposure	66	17	15.63	<0.001
Previous hospitalization	52	15	6.74	0.009
ICU stay >7 days	49	10	10.62	0.001
Septic shock	31	6	5.11	0.024

Patients with MDR infections experienced significantly longer ICU and hospital stays, prolonged mechanical ventilation, and higher rates of septic shock and acute kidney injury compared with those having non-MDR infections. ICU mortality was also significantly higher among patients with MDR infections (32.1% vs. 12.8%; p=0.024) (Table 9).

Table 9. Clinical Outcomes According to MDR Status

Outcome	MDR (n=81)	Non-MDR (n=39)	p value
Mean ICU stay (days)	14.8 ± 6.3	8.5 ± 3.8	<0.001
Mean hospital stay (days)	21.2 ± 8.4	13.4 ± 5.6	<0.001
Mechanical ventilation duration (days)	10.1 ± 4.7	5.8 ± 2.9	<0.001
Septic shock	31 (38.3)	6 (15.4)	0.011
Acute kidney injury	24 (29.6)	5 (12.8)	0.040
ICU mortality	26 (32.1)	5 (12.8)	0.024
Discharged alive	55 (67.9)	34 (87.2)	0.024

Multivariable logistic regression identified prior antibiotic exposure as the strongest independent predictor of MDR infection (adjusted OR=4.53), followed by mechanical ventilation (adjusted OR=3.89). Central venous catheterization, prolonged ICU stay, advanced age, and diabetes mellitus also independently increased the likelihood of MDR infection (Table 10).

Table 10. Multivariable Logistic Regression for Predictors of MDR Infection

Variable	Adjusted OR	95% CI	p value
Age >60 years	2.34	1.11–4.93	0.025
Diabetes mellitus	2.07	1.01–4.27	0.046
Mechanical ventilation	3.89	1.71–8.84	0.001
Central venous catheter	2.74	1.25–6.02	0.012
Prior antibiotic exposure	4.53	2.01–10.18	<0.001
ICU stay >7 days	2.81	1.32–5.98	0.007

Ventilator-associated pneumonia accounted for the highest proportion of MDR infections, followed by bloodstream infections and catheter-associated urinary tract infections. The distribution of MDR organisms differed significantly across infection sources, indicating a strong association between infection site and multidrug resistance (Table 11).

Table 11. Distribution of MDR Organisms According to Infection Source

Infection Source	MDR n (%)	Non-MDR n (%)	Total	p value
Ventilator-associated pneumonia	31	7	38	<0.001
Bloodstream infection	16	8	24	
Catheter-associated UTI	13	9	22	
Surgical site infection	9	6	15	
Intra-abdominal infection	7	4	11	
Skin & soft tissue infection	3	3	6	
Others	2	2	4	

Multidrug-resistant organisms represented over two-thirds of all isolates (67.5%), while extensively drug-resistant organisms accounted for 20.0%. Carbapenem-resistant Enterobacterales and carbapenem-resistant *Acinetobacter baumannii* were the predominant resistant phenotypes. Methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and pandrug-resistant organisms were identified less frequently (Table 12).

Table 12. Prevalence of Specific Resistance Phenotypes

Resistance Phenotype	n (%)
Multidrug-resistant (MDR)	81 (67.5)
Extensively drug-resistant (XDR)	24 (20.0)
Pandrug-resistant (PDR)	4 (3.3)
Carbapenem-resistant Enterobacterales (CRE)	22 (18.3)
Carbapenem-resistant Acinetobacter baumannii (CRAB)	18 (15.0)
Carbapenem-resistant Pseudomonas (CRPA)	10 (8.3)
Methicillin-resistant Staphylococcus aureus (MRSA)	8 (6.7)
Vancomycin-resistant Enterococcus (VRE)	2 (1.7)

DISCUSSION

The present study demonstrated a high prevalence of multidrug-resistant (MDR) organisms (67.5%) among ICU patients, emphasizing the substantial burden of antimicrobial resistance in critically ill populations. *Acinetobacter baumannii* (25.8%) and *Klebsiella pneumoniae* (23.3%) were the predominant pathogens isolated, with *Acinetobacter* exhibiting the highest proportion of MDR isolates. These findings are consistent with reports from lower- and middle-income countries, where Gram-negative bacilli dominate ICU-acquired infections owing to extensive antibiotic exposure, invasive procedures, and prolonged hospitalization [11]. Similarly, Lim et al. reported a pooled MDR prevalence approaching 80% among *A. baumannii* isolates causing hospital-acquired and ventilator-associated pneumonia, highlighting the global emergence of highly resistant Gram-negative pathogens in ICUs [12].

Our study identified ventilator-associated pneumonia as the most common source of infection (31.7%), followed by bloodstream infections and catheter-associated urinary tract infections, reflecting the pivotal role of invasive devices in ICU-acquired infections. Prior antibiotic exposure, mechanical ventilation, prolonged ICU stay, central venous catheterization, and diabetes mellitus emerged as significant independent predictors of MDR infection. These observations closely parallel the findings of Migliara et al., who demonstrated that previous antibiotic therapy substantially increased the risk of MDR *Klebsiella pneumoniae* infections in ICU patients, and a recent meta-analysis by Diao H et al., which identified invasive procedures, prolonged ICU stay, and prior antibiotic use as major determinants of MDR/*XDR Acinetobacter baumannii* infections [13,14]. Our regression analysis similarly showed prior antibiotic exposure and mechanical ventilation as the strongest predictors of MDR infections.

The antimicrobial susceptibility profile observed in the present study demonstrated extensive resistance to β-lactams, cephalosporins, and fluoroquinolones, whereas colistin and tigecycline retained excellent activity against most isolates. These findings are in agreement with contemporary surveillance studies that continue to identify polymyxins and tigecycline as among the few remaining therapeutic options for severe MDR Gram-negative infections, although the emergence of resistance even to these agents remains a growing concern [15,16]. The detection of carbapenem-resistant Enterobacterales (18.3%) and carbapenem-resistant *Acinetobacter baumannii* (15.0%) further underscores the increasing challenge posed by carbapenem resistance in critical care settings and reinforces the importance of antimicrobial stewardship and strict infection-control practices.

Patients with MDR infections experienced significantly longer ICU and hospital stays, prolonged mechanical ventilation, and higher ICU mortality compared with patients infected by non-MDR organisms. These findings corroborate the systematic review by Vardakas et al., which identified multidrug resistance, septic shock, prolonged ICU stay, and inappropriate antimicrobial therapy as major predictors of mortality among patients with MDR Gram-negative infections [15]. Likewise, a large national cohort study by Appaneal et al. reported that MDR *Acinetobacter baumannii* infection

was independently associated with prolonged hospitalization and increased mortality [16]. Collectively, these findings highlight that early microbiological diagnosis, judicious empirical antibiotic selection guided by local antibiograms, implementation of robust antimicrobial stewardship programs, and stringent infection prevention measures remain essential strategies to reduce the clinical burden of MDR infections in intensive care units.

CONCLUSION

The present study highlights the substantial burden of multidrug-resistant infections among critically ill ICU patients, with Gram-negative organisms, particularly *Acinetobacter baumannii* and *Klebsiella pneumoniae*, accounting for the majority of MDR isolates. Prior antibiotic exposure, mechanical ventilation, prolonged ICU stay, and invasive device use were identified as significant predictors of MDR infection, which was associated with longer hospitalization and increased mortality. The observed high resistance to commonly used antibiotics, coupled with preserved susceptibility to colistin and tigecycline, underscores the urgent need for robust antimicrobial stewardship programs, routine microbiological surveillance, early pathogen identification, and stringent infection prevention and control measures. Strengthening these strategies is essential to optimize antimicrobial therapy, curb the emergence of resistance, and improve clinical outcomes among critically ill patients.

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