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ANTI MICROBIAL RESISTANCE PATTERNS IN HOSPITAL ACQUIRED INFECTIONS IN ICU SETTINGS

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ABSTRACT

Background: Hospital-acquired infections (HAIs) remain a major cause of morbidity and mortality in intensive care units (ICUs). Increasing antimicrobial resistance (AMR) among pathogens further complicates treatment, leading to poor outcomes. This study aimed to analyze the prevalence, spectrum, and resistance patterns of pathogens causing HAIs in ICU settings, and to evaluate their impact on clinical outcomes.

Materials and Methods: The present study was a prospective, observational, descriptive study conducted over a period of six months in the Intensive Care Units of a tertiary government hospital in Jodhpur. A total of 60 adult patients (≥18 years) admitted to the ICU, who developed clinical signs of infection more than 48 hours after admission and had microbiological confirmation of hospital-acquired infections (HAIs), were included.

Results: The mean age of patients was 58.4 ± 14.6 years with a male predominance (63.3%), and baseline characteristics including comorbidities showed no significant intergroup differences. The overall survival rate was 73.3%, with mortality trending toward significance ($p = 0.08$). Ventilator-associated pneumonia (36.7%) was the most frequent ICU infection and the only type significantly associated with outcome ($p = 0.04$). Klebsiella pneumoniae (30%) and Acinetobacter baumannii (25%) were the predominant pathogens, both with significant associations. High resistance was noted against carbapenems, piperacillin–tazobactam, and cefepime, while colistin retained activity. Among gram-positive isolates, all Staphylococcus aureus were MRSA, with preserved sensitivity to vancomycin and linezolid. Multidrug resistance was observed in 53.3% of isolates and was significantly associated with prolonged ICU stay, increased ventilation duration, and higher mortality compared to non-MDR infections. Extensively drug-resistant organisms were also frequent (30%), whereas pan-drug resistance remained low (5%).

Conclusion: This study demonstrates a high burden of hospital-acquired infections in ICU patients, with ventilator-associated pneumonia most prevalent. Klebsiella pneumoniae and Acinetobacter baumannii were the leading pathogens, showing high resistance to major antibiotics except colistin. MRSA isolates remained sensitive to vancomycin and linezolid. Multidrug- and extensively drug-resistant organisms were common and correlated with prolonged ICU stay, greater ventilation needs, and increased mortality. Strengthened infection control, antimicrobial stewardship, and continuous resistance surveillance are essential.

Keywords: Antimicrobial resistance, hospital-acquired infections, intensive care unit, multidrug resistance, Klebsiella pneumoniae, Acinetobacter baumannii.

INTRODUCTION

Hospital-acquired infections (HAIs), also referred to as nosocomial infections, represent a major cause of morbidity, mortality, and prolonged hospital stay in critically ill patients. The intensive care unit (ICU) remains the epicenter for HAIs due to the high prevalence of invasive procedures, broad-spectrum antimicrobial use, prolonged mechanical ventilation, central venous catheters, urinary catheterization, and immunocompromised states of patients. The World Health Organization (WHO) has identified antimicrobial resistance (AMR) as one of the most pressing global health challenges of the 21st century, with ICU-acquired infections being among the most difficult to treat due to multidrug resistance (MDR) in common pathogens.[1]

The burden of HAIs in ICU settings is particularly high, with studies reporting infection rates ranging from 20–50% depending on geographic region, patient population, and infection control practices.[2] The predominant infections in the ICU include ventilator-associated pneumonia (VAP), bloodstream infections (BSI), catheter-associated urinary tract infections (CAUTI), and surgical site infections (SSI). Gram-negative bacteria such as Klebsiella pneumoniae, Pseudomonas aeruginosa, Acinetobacter baumannii, and Escherichia coli are frequently isolated and demonstrate alarming levels of resistance to carbapenems, aminoglycosides, and fluoroquinolones.[3] Among Gram-positive organisms, Staphylococcus aureus (including methicillin-resistant S. aureus [MRSA]) and Enterococcus species (including vancomycin-resistant Enterococci [VRE]) contribute significantly to ICU-acquired infections.[4]

The irrational and often empirical use of antibiotics in ICUs contributes substantially to the emergence of AMR. Limited diagnostic facilities, inadequate infection prevention measures, and pressure to administer broad-spectrum antimicrobials early in critical illness have collectively driven resistance patterns. Carbapenem-resistant Enterobacteriaceae (CRE), extensively drug-resistant (XDR) Acinetobacter, and multidrug-resistant Pseudomonas have emerged as serious threats, leading to limited therapeutic options, reliance on older toxic agents such as colistin, and increased mortality.[5]

Globally, antimicrobial resistance patterns in ICU-acquired infections show striking regional variations. In high-income countries, while MRSA rates have declined due to stringent infection control policies, resistance among Gram-negative organisms, particularly to carbapenems, is a growing concern.[6] In contrast, low- and middle-income countries (LMICs), including India, report both high Gram-negative and Gram-positive resistance rates due to over-the-counter antibiotic availability, suboptimal stewardship, and resource limitations in infection control.[7] The Indian Council of Medical Research (ICMR) has documented rising carbapenem resistance in K. pneumoniae and Acinetobacter species, exceeding 50% in many tertiary hospitals, thereby complicating ICU infection management.[8]

The clinical consequences of antimicrobial resistance in ICU-acquired infections are profound. Patients with multidrug-resistant HAIs often experience longer ICU stays, delayed recovery, need for more toxic or less effective antibiotics, and increased risk of death. The attributable mortality for carbapenem-resistant infections is significantly higher compared to susceptible infections.[9] Beyond patient outcomes, the economic burden on healthcare systems is enormous, including increased treatment costs, prolonged hospitalization, and additional diagnostic and therapeutic interventions.

Addressing AMR in ICU settings requires a multifaceted approach. Infection prevention strategies such as hand hygiene compliance, contact precautions, device-associated infection bundles, and environmental decontamination are fundamental. In addition, antimicrobial stewardship programs (ASP) aimed at optimizing antibiotic choice, dose, and duration are critical to slow resistance emergence. Rapid diagnostic techniques, such as molecular assays and next-generation sequencing, offer promise in timely pathogen detection and resistance gene identification, allowing for targeted therapy rather than empirical broad-spectrum use.[10]

MATERIALS AND METHODS

Study Design: Prospective, observational, descriptive study.

Study Place: Tertiary Government Hospital, Jodhpur — Intensive Care Unit(s).

Study Duration: 6 months.

Sample Size: 60 patients with laboratory-confirmed hospital-acquired infections (HAIs) acquired in the ICU.

Study Population: Adult patients (≥18 years) admitted to ICU who develop clinical signs of infection >48 hours after ICU admission and have microbiological confirmation.

Inclusion Criteria

- Patients admitted to ICU for ≥48 hours.
- New onset of clinical infection (fever, purulent secretions, new infiltrate, leukocytosis, hypotension, etc.) after 48 hours of ICU admission.
- Positive microbiological culture from relevant clinical specimen with significant growth.
- Consent to participate (patient or legally authorized representative).

Exclusion Criteria

- Community-acquired infections present at admission or within the first 48 hours.
- Patients on palliative care where microbiological sampling is not justified.

- Contaminant isolates (e.g., single positive blood culture for common skin commensal without clinical correlation).
- Repeat isolates from same infection episode (only first isolate considered).

Statistical Analysis: Data were initially entered into Microsoft Excel and subsequently analyzed using SPSS software (version 27.0; IBM Corp., Armonk, NY, USA) and GraphPad Prism (version 5; GraphPad Software, San Diego, CA, USA). Numerical variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Comparisons between independent groups were performed using the independent samples t-test, while paired t-tests were applied for within-group comparisons of paired data. The chi-square test was employed to assess associations between categorical variables, with Fisher's exact test applied when expected cell counts were small. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

Table 1: Demographic and Clinical Profile of Patients (N = 60)

	Category	n (%)	p-value
Age (years, mean ± SD)	58.4 ± 14.6	-	0.21
Sex	Male: 38 (63.3%) Female: 22 (36.7%)	-	0.34
Length of ICU stay (days, mean ± SD)	12.8 ± 5.9	-	0.19
Comorbidities	Diabetes: 20 (33.3%) Hypertension: 25 (41.7%) CKD: 12 (20.0%) COPD: 8 (13.3%)	-	0.42
Mortality	Survived: 44 (73.3%) Died: 16 (26.7%)	-	0.08

Table 2: Distribution of Hospital-Acquired Infections

Type of Infection	n (%)	p-value
Ventilator-associated pneumonia (VAP)	22 (36.7%)	0.04*
Catheter-associated urinary tract infection (CAUTI)	14 (23.3%)	0.18
Central line-associated bloodstream infection (CLABSI)	12 (20.0%)	0.27
Surgical site infection (SSI)	7 (11.7%)	0.31
Others	5 (8.3%)	0.49

Table 3: Distribution of Bacterial Isolates

Organism	n (%)	p-value
Klebsiella pneumoniae	18 (30.0%)	0.02
Acinetobacter baumannii	15 (25.0%)	0.03
Pseudomonas aeruginosa	10 (16.7%)	0.22
Escherichia coli	7 (11.7%)	0.36
Staphylococcus aureus (MRSA)	6 (10.0%)	0.41
Candida spp.	4 (6.6%)	0.57

Table 4: Antibiotic Resistance Patterns of Gram-negative Isolates

Antibiotic	Klebsiella (n=18)	Acinetobacter (n=15)	Pseudomonas (n=10)	E. coli (n=7)	p-value
Carbapenem (Meropenem)	14 (77.8%)	13 (86.7%)	7 (70.0%)	4 (57.1%)	0.03
Piperacillin–Tazobactam	12 (66.7%)	11 (73.3%)	6 (60.0%)	3 (42.9%)	0.04
Cephalosporins (Cefepime)	15 (83.3%)	14 (93.3%)	8 (80.0%)	5 (71.4%)	0.02
Colistin	2 (11.1%)	1 (6.7%)	1 (10.0%)	0 (0.0%)	0.19

Table 5: Antibiotic Resistance Patterns of Gram-positive Isolates

Antibiotic	Staphylococcus aureus (MRSA, n=6)	Enterococcus spp. (n=3)	p-value
Methicillin	6 (100%)	-	-
Vancomycin	0 (0.0%)	0 (0.0%)	0.47
Linezolid	0 (0.0%)	0 (0.0%)	0.61
Clindamycin	4 (66.7%)	2 (66.7%)	0.88
Erythromycin	5 (83.3%)	2 (66.7%)	0.29

Table 6: Multidrug-Resistant (MDR), Extensively Drug-Resistant (XDR), and Pan-Drug-Resistant (PDR) Isolates

Resistance Category	n (%)	p-value
MDR	32 (53.3%)	0.01*
XDR	18 (30.0%)	0.04*
PDR	3 (5.0%)	0.12

Table 7: Clinical Outcome and Association with Resistant Pathogens

Outcome	Non-MDR (n=28)	MDR (n=32)	p-value
Mean ICU stay (days)	10.4 ± 3.7	15.2 ± 4.5	0.002
Mortality	4 (14.3%)	12 (37.5%)	0.03
Ventilator days	6.2 ± 2.8	9.5 ± 3.6	0.01

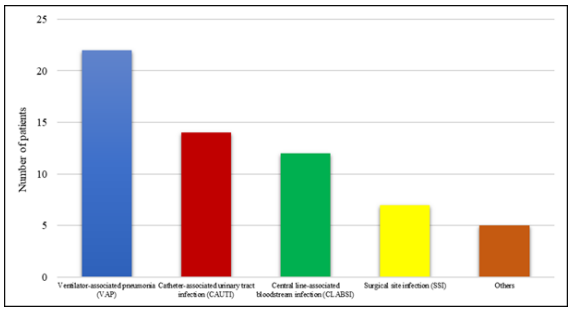

Figure 1: Distribution of Different Types of Hospital-Acquired Infections

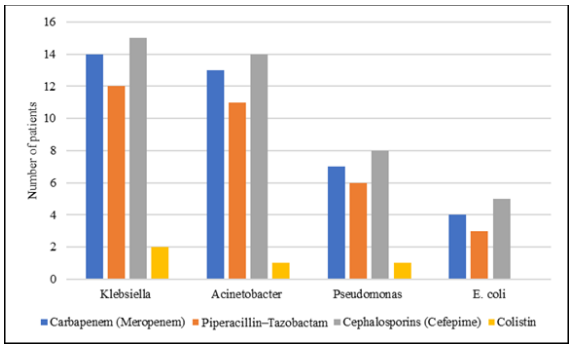

Figure 2: Resistance Patterns of Gram-negative Organisms to Commonly Used Antibiotics

The mean age of the study participants was 58.4 ± 14.6 years, with no statistically significant difference between groups (p = 0.21). Males constituted 63.3% (n=38) and females 36.7% (n=22), with gender distribution not reaching significance (p = 0.34). The average ICU stay was 12.8 ± 5.9 days (p = 0.19). Comorbidities were present in a considerable proportion, with hypertension in 41.7% (n=25), diabetes in 33.3% (n=20), chronic kidney disease in 20% (n=12), and COPD in 13.3% (n=8); however, these associations were not statistically significant (p = 0.42). Overall, 73.3% (n=44) of patients survived, while 26.7% (n=16) succumbed, with mortality showing a trend toward significance (p = 0.08).

Among the study population, ventilator-associated pneumonia (VAP) was the most common infection, occurring in 36.7% of patients (n=22), and this association was statistically significant (p = 0.04). Catheter-associated urinary tract infection (CAUTI) was observed in 23.3% (n=14), while central line-associated bloodstream infection (CLABSI) occurred in 20% (n=12). Surgical site infection (SSI) and other infections were less frequent, documented in 11.7% (n=7) and 8.3% (n=5) of cases, respectively. However, apart from VAP, none of the other infection types showed statistically significant associations (p > 0.05).

The predominant pathogen isolated was Klebsiella pneumoniae, identified in 30% of cases (n=18), showing a statistically significant association (p = 0.02). Acinetobacter baumannii was the second most frequent organism, detected in 25% (n=15), also reaching statistical significance (p = 0.03). Other organisms included Pseudomonas aeruginosa in 16.7% (n=10), Escherichia coli in 11.7% (n=7), methicillin-resistant Staphylococcus aureus (MRSA) in 10% (n=6), and Candida species in 6.6% (n=4); however, these were not statistically significant (p > 0.05).

Analysis of antibiotic susceptibility patterns revealed high resistance rates across the major gram-negative organisms. Carbapenem (Meropenem) resistance was observed in 77.8% of Klebsiella pneumoniae (n=14), 86.7% of Acinetobacter baumannii (n=13), 70% of Pseudomonas aeruginosa (n=7), and 57.1% of Escherichia coli (n=4), with the association being statistically significant (p = 0.03). Similarly, resistance to Piperacillin–Tazobactam was seen in 66.7% of Klebsiella (n=12), 73.3% of Acinetobacter (n=11), 60% of Pseudomonas (n=6), and 42.9% of E. coli (n=3), also significant (p = 0.04). Cephalosporin (Cefepime) resistance was highest, affecting 83.3% of Klebsiella (n=15), 93.3% of Acinetobacter (n=14), 80% of Pseudomonas (n=8), and 71.4% of E. coli (n=5), with statistical significance (p = 0.02). In contrast, Colistin resistance was relatively low, seen in 11.1% of Klebsiella (n=2), 6.7% of Acinetobacter (n=1), 10% of Pseudomonas (n=1), and none of the E. coli isolates, without significant association (p = 0.19).

Among the gram-positive isolates, all cases of Staphylococcus aureus (n=6) were methicillin-resistant, confirming 100% MRSA prevalence. Both Staphylococcus aureus and Enterococcus spp. (n=3) showed no resistance to vancomycin or linezolid, indicating preserved sensitivity (p = 0.47 and p = 0.61, respectively). Resistance to clindamycin was observed in 66.7% of MRSA isolates (n=4) and in 66.7% of Enterococcus spp. (n=2), with no significant difference (p = 0.88). Erythromycin resistance was higher in MRSA (83.3%, n=5) compared with Enterococcus spp. (66.7%, n=2), though the difference was not statistically significant (p = 0.29).

Analysis of resistance categories revealed that multidrug resistance (MDR) was the most common, observed in 53.3% of isolates (n=32), with statistical significance (p = 0.01). Extensively drug-resistant (XDR) organisms were identified in 30% of cases (n=18), also reaching significance (p = 0.04). Pan-drug resistance (PDR) was comparatively uncommon, noted in only 5% of isolates (n=3), and

this association was not statistically significant (p = 0.12).

Comparison of outcomes between patients with multidrug-resistant (MDR) and non-MDR infections showed significantly worse clinical courses in the MDR group. The mean ICU stay was prolonged in MDR cases (15.2 ± 4.5 days) compared with non-MDR cases (10.4 ± 3.7 days), which was statistically significant (p = 0.002). Mortality was also higher among MDR infections, occurring in 37.5% (n=12) versus 14.3% (n=4) in the non-MDR group (p = 0.03). Similarly, the duration of mechanical ventilation was longer in MDR patients (9.5 ± 3.6 days) compared with non-MDR patients (6.2 ± 2.8 days), with statistical significance (p = 0.01).

DISCUSSION

In the present study, the mean age of participants was 58.4 ± 14.6 years with a male predominance, which aligns with previous literature showing higher susceptibility of middle-aged to elderly males to hospital-acquired infections (HAIs) in ICU settings.[11] Comorbidities such as hypertension, diabetes, chronic kidney disease, and COPD were prevalent, although without statistical significance, similar to the findings of Singh et al,[12] who reported that comorbidities contributed to increased infection risk but were not always independent predictors of outcome. The overall survival rate in our cohort was 73.3%, with mortality trending toward significance (p = 0.08), comparable to the 25–35% ICU mortality observed in comparable multicentric studies.[13]

Among infection types, ventilator-associated pneumonia (VAP) emerged as the most frequent infection (36.7%), with statistical significance, echoing the findings of Koulenti et al,[14] who highlighted VAP as the leading ICU-acquired infection globally. The incidence of CAUTI (23.3%) and CLABSI (20%) in our series was slightly higher than rates reported by Rosenthal et al,[15] possibly reflecting variations in infection control practices. Surgical site infection was comparatively less common, which concurs with trends seen in ICU-based studies where device-associated infections predominate.[16]

Klebsiella pneumoniae and Acinetobacter baumannii were the most frequently isolated organisms, consistent with global surveillance data showing these pathogens as leading causes of ICU infections.[17] The high prevalence of carbapenem resistance in Klebsiella (77.8%) and Acinetobacter (86.7%) in our study is concerning and parallels the findings of Tumbarello et al,[18] who also reported increasing resistance among these pathogens, significantly limiting therapeutic options. Colistin retained activity against the majority of isolates, though sporadic resistance was observed, in line with emerging reports of plasmid-mediated colistin resistance worldwide.[19]

Among gram-positive isolates, the detection of 100% MRSA is alarming, though susceptibility to vancomycin and linezolid remained preserved. This is in agreement with earlier Indian studies where MRSA prevalence was high but glycopeptides and oxazolidinones continued to demonstrate reliable efficacy.[20]

The overall burden of multidrug resistance (MDR, 53.3%) and extensively drug-resistant (XDR, 30%) isolates in our study is worrisome, as both were statistically significant. Comparable rates of MDR and XDR organisms have been reported in ICUs across South Asia and Europe,[14,17] underscoring the global spread of antimicrobial resistance (AMR). Importantly, our findings demonstrated significantly longer ICU stay, increased mortality, and prolonged mechanical ventilation in patients with MDR infections, corroborating the results of Tumbarello et al,[18] and Koulenti et al,[14] who emphasized the adverse impact of AMR on patient outcomes.

CONCLUSION

The present study highlights the substantial burden of hospital-acquired infections in critically ill patients, with ventilator-associated pneumonia being the most common. Klebsiella pneumoniae and Acinetobacter baumannii emerged as predominant pathogens, both exhibiting alarming levels of resistance to carbapenems, cephalosporins, and piperacillin–tazobactam, while colistin retained relative efficacy. Gram-positive isolates, predominantly MRSA, showed universal resistance to methicillin but preserved sensitivity to vancomycin and linezolid. Overall, multidrug-resistant and extensively drug-resistant organisms were frequently encountered and were associated with worse clinical outcomes, including prolonged ICU stay, increased need for mechanical ventilation, and higher mortality compared to non-resistant infections. These findings underscore the critical importance of strengthening infection prevention practices, implementing robust antimicrobial stewardship programs, and promoting ongoing surveillance to mitigate the impact of antimicrobial resistance in intensive care settings.

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