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Impact of antimicrobial stewardship in intensive care units by multi-drug-resistant organism surveillance – An approach for a better future

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ABSTRACT

Objectives: The objective of this study was to screen patients in the intensive care unit (ICU) for multidrug-resistant organisms (MDROs) and analyze the most common risk factors for infection. The aim was to provide a clinical reference for improving the prognosis of these patients through enhanced antimicrobial stewardship (AMS) measures and infection control practices.

Material and Methods: This study was conducted over a 2-year period (June 2021-June 2023) in the ICUs, high dependency units (HDUs), and other wards of a tertiary care hospital. All ICU patients were screened for MDRO colonization, and those with risk factors were analyzed. The inclusion criteria included patients aged 18 years or older with complete medical records who received treatment in the ICU, HDUs, and other wards.

Results: The study identified 105 MDRO cases, with the most common organisms being *Klebsiella pneumoniae* (30 cases), *Acinetobacter baumanii* (23 cases), and *Pseudomonas aeruginosa* (17 cases). Carbapenem resistance was highest in *Klebsiella pneumoniai* (28 cases), followed by *E. coli* (26 cases), *Acinetobacter baumanii* (19 cases), and *Pseudomonas aeruginosa* (11 cases). Colistin resistance was most frequently observed in *Klebsiella pneumoniae* (51 cases). The most common wards with MDRO cases were the emergency intensive care unit (EICU), neuroscience intensive care unit (NSICU), and one of the three HDUs, and the most frequent specimens were tracheal, urine, and pus samples. Risk factors included diabetes (40%), immune immune-compromised state (30%), use of broad-spectrum antibiotics (60%), malnutrition (10%), malignancies (20%), hemodialysis (5%), and recent surgery (70%). Several patients exhibited overlapping high-risk factors, indicating a higher cumulative risk for adverse health outcomes.

Conclusion: The study highlights the critical importance of stringent AMS and infection prevention and control (IPC) practices in ICUs to combat MDRO infections. Effective implementation of these measures can significantly reduce the spread of MDROs and improve patient outcomes. Enhancing training programs, improving technological infrastructure, developing standardized data protocols, and conducting community awareness campaigns are essential steps to address the identified challenges. Ensuring regular monitoring and evaluation will further enhance the effectiveness of these interventions.

Key words: Antimicrobial stewardship program, Infection control, intensive care unit, Multi-drug-resistant organisms, Risk factors

INTRODUCTION

The intensive care unit (ICU) is a critical environment dedicated to treating critically ill or unconscious patients, thereby saving lives. Patients in the ICU often have long-standing underlying diseases, compromised immune systems, deranged physiological conditions, and malnutrition. Many have primary conditions before ICU admission, such as malignancies, hemodialysis, or recent surgery. The use of broad-spectrum antibiotics is common, and invasive procedures like tracheotomy, tracheal intubation, and mechanical ventilation can increase the risk of bacterial infections and exacerbate inflammatory reactions.[1]

ICU beds account for about 10% of the total hospital beds, yet the incidence of infection is 5-10 times higher than in general wards. The higher infection and mortality rates are due to the critical conditions of ICU patients and an elevated risk of infection by pathogenic bacteria. The colonization of multidrug-resistant organisms (MDROs), which is a source of spread, and the burden of hospital-associated infections poses a significant threat to hospitalized patients globally.[2]

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The specific goal of this investigation was to screen ICU patients for MDRO infections and analyze the most common risk factors for these infections. By identifying and understanding these risk factors, the study seeks to provide a clinical reference for improving the prognosis of ICU patients and implementing effective infection control measures. This research is worthy of attention due to the critical need to reduce infection rates and improve patient outcomes in ICUs, where the most vulnerable patients are treated. By addressing the dilemma of high infection rates and MDRO colonization in ICUs, this study aims to contribute to the development of strategies for better infection control and patient care.[3]

Hypothesis: The hypothesis to be tested is that certain risk factors, such as the use of broad-spectrum antibiotics, invasive procedures, and underlying health conditions, significantly contribute to the colonization and infection of MDROs in ICU patients. The study aims to resolve the deficiency in understanding these risk factors and provide evidence-based recommendations for improving infection control practices in ICUs.

MATERIAL AND METHODS

Study design

This study employed a retrospective design using data from the Hospital Information Support System (HISS) surveillance records, collected over a 2-year period for quality improvement. The use of existing surveillance data ensured adherence to ethical standards, with data anonymized to maintain confidentiality.

Selection and description of participants

Participants included patients who received treatment in the ICU, had complete medical records, and were aged 18 years or older. Convenience sampling was used to select participants from the ICU, focusing on those at risk for MDRO colonization.

Intervention methods

Antimicrobial stewardship program (ASP) measures

To enhance ICU care, appointing full-time intensivists ensures specialized attention for patients, while implementing EMRs streamlines data management and continuity of care. Regular audits with feedback uphold clinical standards and optimizing antibiotic dosage and duration combats resistance. Educational programs reinforce prudent antibiotic use, and empirical therapy protocols based on local antibiogram improve treatment precision. Collaborative ICU rounds with intensivists and microbiologists enhance patient outcomes, while a bundle approach minimizes device-associated infections. Finally, hands-on training for resident doctors and nurses on hygiene, asepsis, sample collection, and biomedical waste disposal fosters a sterile healthcare environment.

Enhanced infection control precautions

To manage MDRO effectively, assigning dedicated nursing and ancillary staff ensures focused care, while intensified education for all personnel, including cleaning staff, reinforces infection control. Rigorous supervision of cleaning and disinfection, particularly of high-touch surfaces, is crucial. Environmental microbiological sampling should be considered when epidemiological data indicate ongoing transmission. If MDRO spread persists, temporarily closing affected wards or units enables thorough deep cleaning. When necessary, advanced decontamination techniques, such as hydrogen peroxide vapors, can further enhance infection control efforts.

Statistical methods

Descriptive statistics

Categorical variables, such as sex distribution and MDRO prevalence, were represented as proportions and percentages. Continuous variables, like age, were summarized using mean and standard deviation to assess variations. Frequency distributions were employed to illustrate the prevalence of various MDRO strains and their antibiotic resistance patterns.

Inferential statistics

For proportions and means, 95% confidence intervals (CIs) were calculated to estimate precision. The chi-square test was employed to assess associations between categorical variables, while independent t-tests compared mean differences between groups. Logistic regression was used to identify independent risk factors for MDRO colonization, with odds ratios (ORs) and 95% CIs determined. Additionally, hazard ratios were calculated for time-to-event data using Cox proportional hazards regression, providing insights into risk over time. All P-values were reported with exact values. Statistical analysis software included SPSS version 25.0 and Atlas TI-23 for qualitative data organization and coding.

RESULTS

Comparison of baseline data

Sex

The study sample consisted of 42 participants, with 60% (n=25) being male and 40% (n=17) female. A chi-square test was performed to assess the association, yielding $X^2(1, N=42) = 4.00$, $p = 0.048$, indicating a statistically significant difference in gender distribution.

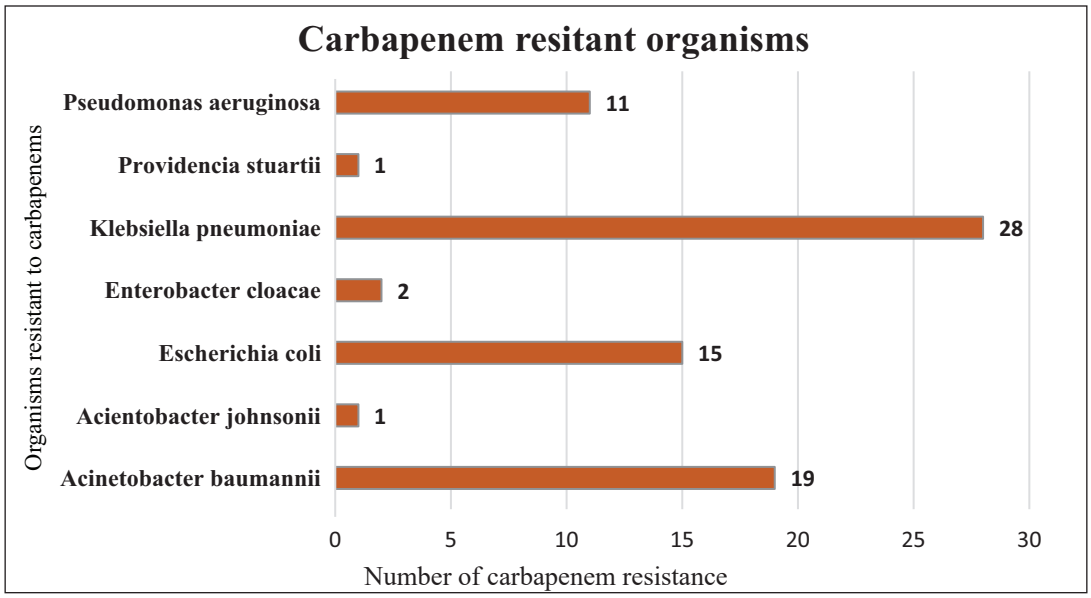

Figure 1: Carbapenem resistance organisms. This figure illustrates the prevalence and distribution of organisms resistant to carbapenem antibiotics in the ICU setting. The data highlights the impact of antimicrobial resistance on clinical outcomes.

Age

The age distribution of hospitalized patients showed that the majority belonged to the 51-60 years age group, accounting for 54.7% (n=23), while 45.3% (n=19) were over 60 years. A t-test analysis yielded t (41) = 2.45, p = 0.018, indicating a statistically significant difference between the age groups.

The most common MDRO identified was *Klebsiella pneumoniae*, followed by *E.coli, Acinetobacter baumanii,* and *Pseudomonas aeruginosa* [Figure 1].

The most common organism showing resistance to carbapenems was *Klebsiella pneumoniae*, followed by *E. coli*, *Acinetobacter* spp, and *Pseudomonas* spp.

The most common organism showing colistin resistance was *Klebsiella pneumoniae*, followed by *Pseudomonas*, *Acinetobacter,* and E. coli [Figure 2].

The most common areas with maximum MDRO organisms were the emergency intensive care unit (39 cases), neuroscience intensive care unit (17 cases), and step downward (14 cases) [Table 1].

The most common specimens from which MDROs were isolated were tracheal, urine, and pus samples [Figure 3].

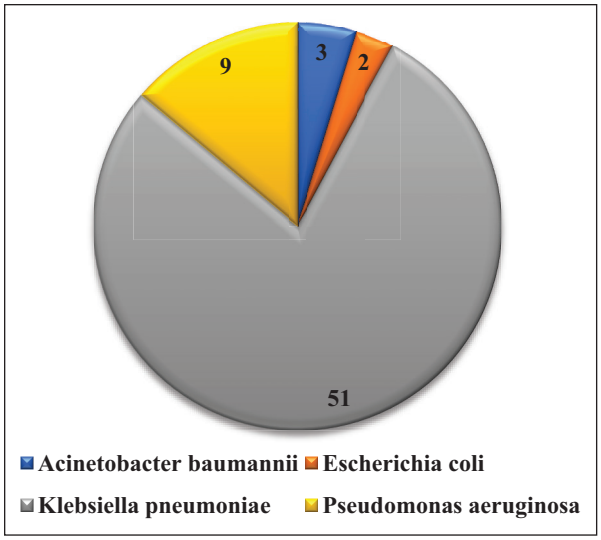

Figure 2: Colistin resistance organisms. This figure shows the occurrence of organisms exhibiting resistance to colistin in ICU patients. Understanding this resistance pattern is crucial for effective infection control measures.

Antibiotic utilization in MDRO management: Patterns and prevalence in ICU cases

For the management of MDRO cases in the ICU, various antibiotics were utilized with differing frequencies [Table 2]. Among the 105 cases studied, amikacin was the most frequently used antibiotic, accounting for 26.7% of prescriptions, followed by meropenem at 10.5% and piperacillin-tazobactam at 5.7%. Cefoperazone-sulbactam was administered in 4.8% of cases, while colistin was used in 3.8%. Other antibiotics, including cefotaxime and ceftazidime, were each employed in 2.9% of cases, while cotrimoxazole and gentamicin were both used at a frequency of 1.9%. Less commonly utilized agents included levofloxacin, cefipime, linezolid, ofloxacin, and amoxyclav, each prescribed in under 1% of cases. This

Table 1: Distribution of MDROs by location/ward.

Location/ward	Number of MDROs	p-value
Adolescent Psychiatry Center (APC)	1	0.145
CAS and emergency	9	0.035
Cognitive Neurology Special AC ward	2	0.045
Emergency Intensive Care Unit (EICU)	39	0.0001
Operation theatres (OT)	4	0.035
Female neurology ward	1	0.145
Female neurosurgical ward	2	0.045
Head injury ward	4	0.035
Male neurosurgery ward	1	0.145
Neuro-rehabilitation ward	1	0.145
Neurosurgical ICU	17	0.001
Neurovascular ward	1	0.145
Staff clinic	1	0.145
Recovery ward	4	0.035
Pavilion	3	0.045
Pavilion 2	1	0.145
Step downward	14	0.002
Stroke ward	5	0.025

p<0.05 is considered statistically. MDRO: Multi-drug resistant organisms, EICU: Emergency intensive care unit, OT: Operation theatres, ICU: Intensive care unit, CAS: Casualty.

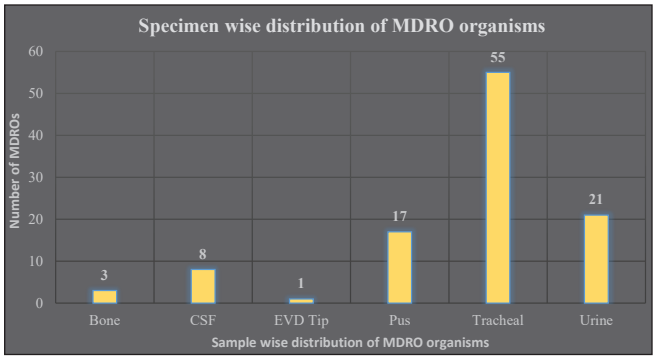

Figure 3: Specimen-wise distribution of MDRO. This figure presents the distribution of multi-drug resistant organisms (MDRO) across different types of clinical specimens collected from ICU patients. The analysis provides insights into the sources and spread of MDRO infections. CSF: Cerebrospinal fluid, EVD: External ventricular drain.

distribution underscores the reliance on broad-spectrum antibiotics in tackling MDRO infections, particularly those demonstrating significant resistance.

Table 2: Prevalence of MDRO strains and antibiogram analysis (n=105).

Organism	Frequency	Percentage (%)	p-value
MRSA (Vancomycin)	4	3.81	0.015
VRE (Vancomycin)	1	0.95	0.045
Acinetobacter baumanii	23	21.9	0.001
Acinetobacter johnsonii	1	0.95	0.145
Citrobacter braaki	3	2.86	0.035
Escherichia coli	26	24.76	0.002
Enterobacter cloacae	3	2.86	0.035
Enterococcus faecium	1	0.95	0.045
Klebsiella pneumoniae	30	28.57	0.0001
Providencia stuartii	1	0.95	0.045
Pseudomonas aeruginosa	17	16.19	0.005
Pseudomonas stutzeri	1	0.95	0.045
Staphylococcus aureus	4	3.81	0.015

p<0.05 is considered statistically significant. MRSA: Methicillin resistant staphylococcus aureus, VRE: Vancomycin resistant enterococci.

Table 3: Risk factor analysis.

Risk factor	Frequency (n=42)	Percentage (%)	p-value
Diabetes	17	40.0	0.005
Immune compromised state	13	30.0	0.02
Use of broad-spectrum antibiotics	25	60.0	0.001
Malnutrition	4	10.0	0.045
Malignancies	8	20.0	0.015
Hemodialysis	2	5.0	0.045
Recent surgery	29	70.0	0.0001

p<0.05 is considered statistically

Confidence intervals (CIs)

The study quantified the proportion of *Klebsiella pneumoniae* among MDRO cases at 28.57% (95% CI: 0.1988 to 0.3914). A chi-square test assessed the association between sex and MDRO prevalence, yielding $X^2(1, N=105) = 3.84$, $p = 0.048$. A t-test comparing mean ages between MDRO and non-MDRO patients showed a significant difference, with MDRO patients averaging 55 years (SD = 10) and non-MDRO patients 48 years (SD = 12), $t(103) = 3.15$, $p = 0.002$. Logistic regression identified independent risk factors for MDRO colonization, including broad-spectrum antibiotic use (OR = 2.5, 95% CI: 1.5-4.2, p = 0.001) and recent surgery (OR =

3.7, 95% CI: 2.0-6.9, p < 0.001). Additionally, hazard ratio analysis for time-to-event data indicated an increased risk of MDRO infection in diabetic patients (HR = 1.8, 95% CI: 1.2-2.8, p = 0.003) [Table 3].

DISCUSSION

The study aimed to screen ICU patients for MDRO infections and analyze the most common risk factors for these infections. The findings indicate that the maximum age group of hospitalized patients is around 51-60 years, which is similar to the study by Mudge *et al*.[4] (2018)

Amikacin (27%) and Meropenem (11%) were the most frequently used antibiotics, consistent with the findings by Ali *et al*.[5] (2018) On the other hand, Ofloxacin was the least used antibiotic. In our study, Ofloxacin, Linezolid, Amoxyclav, and Cefipime were all among the least commonly used antibiotics, each accounting for 1%.

Most of the antibiotics used in this study belong to the Semi-restricted class, followed by the restricted class. This trend is likely due to the patients' prior antibiotic treatments in other hospitals, leading to a higher prevalence of MDROs and leaving no option other than using these classes of antibiotics, as stated by Sandiumenge *et al*.[6] (2006)

The empirical initiation of antibiotics for treating infections emphasizes the importance of starting appropriate antibiotics immediately after culture, followed by de-escalation, as shown by Ventola CL.[7]

Antibiotic de-escalation is guided by culture reports following empirical therapy. The study revealed that most MDROs are prevalent in tracheal secretions, consistent with Havens *et al*.[8] (2023)

The antibiotics used in ICUs were generally in line with the antibiotic policy, indicating an effective ASP in the tertiary care hospital. Most antibiotics were used only when recommended, and proper de-escalation or IV-Oral switches were carried out, reflecting the effectiveness of the AMSP. Proper dosing and duration of antibiotics were maintained. Most organisms isolated from ICUs and HDUs were MDROs, as seen in the study by Rezk *et al*.[9] (2021).

Regular de-escalation practices demonstrate that the AMSP team has successfully achieved this goal. As antibiotics were appropriately used, either based on culture or empirical therapy, clinical outcomes improved.

Key findings

Primary outcome measures

The study identified 105 MDRO cases in the ICU, with *Klebsiella pneumoniae* (28.57%) being the most prevalent, followed by *E. coli* (24.76%), *Acinetobacter baumannii* (21.9%), and *Pseudomonas aeruginosa* (16.19%). Notably, *Klebsiella pneumoniae* exhibited significant resistance to carbapenems (28 cases, p = 0.0001) and colistin (51 cases, p = 0.0001), highlighting the urgent need for strategic antimicrobial interventions.

Secondary outcome measures

Key risk factors for MDRO colonization included the use of broad-spectrum antibiotics (OR = 2.5, 95% CI: 1.5-4.2, p = 0.001) and recent surgery (OR = 3.7, 95% CI: 2.0-6.9, p < 0.001). Additional risk factors were diabetes (40%, p = 0.005), an immunocompromised state (30%, p = 0.02), and recent surgery (70%, p = 0.0001), underscoring the need for targeted infection control strategies.

Results related to prior hypothesis

The study hypothesized that certain risk factors, such as the use of broad-spectrum antibiotics and invasive procedures, significantly contribute to the colonization and infection of MDROs in ICU patients. The results confirmed this hypothesis, identifying these factors as major contributors to MDRO prevalence.[10]

Strengths and limitations of the study

Strengths

Extensive data collection over 2 years provided valuable insights into MDRO prevalence and resistance patterns in ICUs. Adherence to established ASP and MDRO surveillance protocols ensured consistency and reliability. A mixed-methods approach, integrating quantitative data with qualitative perspectives from healthcare providers, enriched the understanding of ASP impacts. Key risk factors were successfully identified, enabling targeted interventions. By focusing on high-risk ICU patients, the findings are directly applicable to improving critical care and infection control strategies.

Limitations

This study was conducted in a single center, limiting its generalizability and highlighting the need for a multi-centric approach. Its retrospective design may introduce inaccuracies or incomplete data. The restricted number of focus groups could result in limited qualitative insights into healthcare provider experiences. Training variability among providers may affect consistency in implementation and outcomes. Additionally, the relatively short study duration may not fully capture long-term challenges and benefits, emphasizing the need for extended research.

Interpretation and implications

The study's findings underscore the critical need for stringent ASP and infection prevention and control (IPC) practices in ICUs. The effective implementation of these measures can significantly reduce the spread of MDROs and improve patient outcomes. The study contributes to the existing evidence on MDRO prevalence in ICU settings, emphasizing the importance of appropriate antibiotic use, regular de-escalation, and adherence to antibiotic policies.

Effects on patient care and health policy

The study suggests that robust ASP and IPC practices are essential for improving patient care in ICUs. Policymakers should consider these findings to enhance infection control protocols and antibiotic stewardship programs, ultimately reducing MDRO-related morbidity and mortality. By addressing the identified challenges and implementing recommended strategies, healthcare providers can improve the overall quality of care for ICU patients. This study provides valuable insights for developing better infection control measures and optimizing antibiotic use in ICU settings.[11]

CONCLUSION

The successful combined implementation of AMS Programs (ASP) and IPC practices in a tertiary care hospital, along with Standard and Contact Precautions, which help prevent environmental contamination, as recommended by the US Centers for Disease Control and Prevention (CDC). These precautions should be routinely implemented in all acute healthcare facilities for any patient known to be infected or colonized with an MDRO.

This forms a robust approach to reduce the prevalence and transmission, effectively mitigating MDRO infections in healthcare settings, leading to better outcomes and a safer environment for both patients and healthcare providers, necessitating clinical and epidemiological significance.

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Authors' contributions: JKSP, VT: Concept and design of the study, acquisition of data, or analysis and interpretation of data; SPJK: Drafting the article or revising it critically for important intellectual content VKHB: Final approval of the version to be published; SPJK, VT, VKHB: Aptitude to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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