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Risk Factors And Clinical Outcomes Associated With Multidrug-Resistant Infections Among Postoperative Patients Admitted To The Intensive Care Unit: A Case-Control Study.

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Abstract

Background: Multidrug-resistant infections are an increasing challenge in intensive care units, particularly among postoperative patients who frequently require broad-spectrum antibiotics, mechanical ventilation, invasive devices, and prolonged hospitalization. MDR infections may delay effective antimicrobial therapy and are associated with sepsis, prolonged organ support, increased ICU stay, and mortality. Identification of modifiable risk factors is therefore essential for prevention and appropriate antimicrobial stewardship. ***Aim:*** To evaluate the risk factors and clinical outcomes associated with multidrug-resistant infections among postoperative patients admitted to the Intensive Care Unit. ***Materials and Methods:*** This hospital-based prospective case-control study included 120 postoperative ICU patients, comprising 60 patients with culture-confirmed MDR infections and 60 controls without MDR infection. Demographic characteristics, comorbidities, surgical variables, previous hospitalization, prior antimicrobial exposure, mechanical ventilation, invasive device use, re-intubation, reoperation, and duration of ICU stay were recorded. Microbiological isolates and infection sites were documented. Clinical outcomes including septic shock, vasopressor requirement, prolonged mechanical ventilation, ICU stay, hospital stay, and in-hospital mortality were compared between cases and controls. ***Results:*** Patients with MDR infection were older than controls (58.6 ± 13.4 vs 53.2 ± 14.1 years; p=0.034). Diabetes mellitus (48.3% vs 30.0%; p=0.040), chronic kidney disease (23.3% vs 10.0%; p=0.049), ASA III/IV status (61.7% vs 41.7%; p=0.028), emergency surgery (53.3% vs 33.3%; p=0.027), and previous hospitalization within 90 days (50.0% vs 26.7%; p=0.009) were more frequent among cases. Klebsiella pneumoniae (30.0%) was the most common MDR organism, followed by Acinetobacter baumannii (23.3%), Escherichia coli (18.3%), and Pseudomonas aeruginosa (13.3%). Hospital/ventilator-associated pneumonia was the most common infection type (31.7%). Prior antibiotic exposure (70.0% vs 36.7%; OR 4.03; p<0.001), carbapenem exposure (45.0% vs 16.7%; OR 4.09; p=0.001), mechanical ventilation >48 hours (65.0% vs 35.0%; OR 3.45; p=0.001), central venous catheterization >5 days (58.3% vs 30.0%; OR 3.27; p=0.002), and ICU exposure >7 days (68.3% vs 40.0%; OR 3.24; p=0.002) were significantly associated with MDR infection. On multivariable analysis, previous hospitalization (aOR 2.48), prior broad-spectrum antibiotic exposure (aOR 3.21), carbapenem exposure (aOR 3.08), mechanical ventilation >48 hours (aOR 2.76), prolonged central venous catheterization (aOR 2.51), and ICU exposure >7 days (aOR 2.69) remained independent predictors. MDR cases had significantly higher septic shock (43.3% vs 16.7%; p=0.001), longer median ICU stay (13 vs 7 days; p<0.001), longer hospital stay (22 vs 13 days; p<0.001), and greater in-hospital mortality (28.3% vs 10.0%; p=0.011). ***Conclusion:*** Multidrug-resistant infections among postoperative ICU patients were strongly associated with previous healthcare exposure, broad-spectrum and carbapenem antibiotic use, prolonged mechanical ventilation, invasive devices, and longer ICU stay. MDR infections were predominantly caused by Gram-negative organisms and were associated with substantially increased morbidity, resource utilization, and mortality. Strengthened antimicrobial stewardship, infection-prevention practices, early removal of invasive devices, and timely microbiological diagnosis are essential to reduce MDR-related adverse outcomes in postoperative ICU patients.

Keywords: Multidrug-resistant infection; postoperative ICU; antimicrobial resistance; carbapenem resistance; mechanical ventilation.

INTRODUCTION

Antimicrobial resistance (AMR) has emerged as one of the most serious threats to modern healthcare, particularly among critically ill patients requiring intensive care and those undergoing major surgical procedures. Multidrug-resistant (MDR) organisms are of particular concern because resistance to multiple antimicrobial classes substantially restricts effective therapeutic options and increases the likelihood of inappropriate initial antimicrobial treatment. According to internationally accepted definitions, multidrug resistance is generally defined as acquired non-susceptibility to at least one agent in three or more antimicrobial categories.[1] Intensive care units (ICUs) provide an environment particularly conducive to the emergence and transmission of MDR organisms because critically ill patients frequently require broad-spectrum antibiotics, prolonged hospitalization, mechanical ventilation, central venous catheterization, urinary catheterization, repeated invasive procedures, and close interaction with healthcare personnel and the hospital environment. Postoperative ICU patients constitute an especially vulnerable population because surgical stress, tissue injury, impaired host defenses, blood loss, transfusion, invasive devices, prolonged operative procedures, and postoperative organ dysfunction may further increase susceptibility to healthcare-associated infection.

The global burden of bacterial AMR is substantial; a systematic analysis of 204 countries and territories estimated that bacterial AMR was directly responsible for approximately 1.27 million deaths and associated with 4.95 million deaths globally in 2019.[2] This burden was particularly pronounced for lower respiratory, bloodstream, and intra-abdominal infections, which are commonly encountered among critically ill and postoperative patients. The World Health Organization has identified resistant Gram-negative organisms, including carbapenem-resistant Acinetobacter baumannii and Enterobacterales, as critical-priority pathogens because of their substantial disease burden, limited therapeutic options, and capacity for transmission within healthcare settings.[3] Postoperative infections caused by MDR organisms may manifest as surgical-site infections, ventilator-associated or hospital-acquired pneumonia, bloodstream infections, catheter-associated urinary tract infections, and intra-abdominal infections. Surgical-site infections caused by MDR organisms are particularly challenging because they may result in wound dehiscence, repeated surgical interventions, prolonged antimicrobial treatment, delayed recovery, and extended hospitalization. Foschi et al., in a case-control study of general surgical patients with surgical-site infections, demonstrated the clinical relevance of MDR organisms and highlighted prior healthcare and antimicrobial exposures among factors contributing to resistant infections.[4]

Previous exposure to broad-spectrum antimicrobial agents is one of the most consistently recognized modifiable factors associated with subsequent MDR infection, because antibiotic pressure facilitates selection and persistence of resistant bacterial populations. Other reported risk factors include prolonged hospitalization before ICU admission, previous ICU stay, prior colonization with resistant organisms, mechanical ventilation, central venous and urinary catheters, repeated invasive procedures, high illness-severity scores, comorbid illnesses, immunosuppression, and prolonged ICU stay. The clinical consequences of MDR infections extend beyond microbiological resistance because delay in effective antimicrobial therapy may contribute to progression of infection, sepsis, septic shock, multiorgan dysfunction, prolonged mechanical ventilation, increased ICU stay, and mortality. Contemporary ICU evidence continues to demonstrate substantial MDR and extensively drug-resistant infection burdens and their association with adverse outcomes among critically ill patients.[5]

The problem is particularly important in India, where high antimicrobial consumption, heterogeneous prescribing practices, heavy infectious-disease burden, overcrowding of healthcare facilities, and differences in infection-prevention resources contribute to selection and transmission of resistant organisms. Indian data have demonstrated a substantial mortality burden attributable to resistant pathogens; Gandra et al. reported significantly greater mortality associated with multidrug-resistant and extensively drug-resistant infections in a large Indian hospital network, highlighting the direct clinical consequences of antimicrobial resistance.[6] Indian ICU studies have additionally documented the epidemiological importance of MDR infections during inter-ICU transfer and demonstrated that prolonged mechanical ventilation and longer ICU stay were important determinants of adverse outcomes among patients with MDR infections.[7] Recent multicentre Indian ICU evidence has further identified Klebsiella pneumoniae, Acinetobacter baumannii, Escherichia coli, and Pseudomonas aeruginosa among clinically important multidrug-resistant Gram-negative pathogens, emphasizing the continuing burden of resistant infections in Indian critical-care settings.

Understanding the risk profile specifically among postoperative ICU patients is important because several contributing factors, including antimicrobial exposure, duration of invasive devices, mechanical ventilation, infection-control practices, and duration of ICU stay, are potentially modifiable. A case-control design provides an appropriate framework for comparing postoperative ICU patients who develop culture-confirmed MDR infections with comparable postoperative ICU patients without MDR infections and thereby identifying independent predictors after controlling for potential confounding factors. Evaluation of clinical outcomes such as duration of mechanical ventilation, ICU and hospital length of stay, septic shock, requirement for organ support, and mortality can additionally quantify the clinical burden associated with resistant infection. Identification of these predictors can facilitate risk-based surveillance, early microbiological sampling, appropriate empirical antimicrobial selection, antimicrobial de-escalation, strengthened infection-prevention practices, and

effective antimicrobial stewardship. Therefore, the present study was undertaken to evaluate the risk factors and clinical outcomes of multidrug-resistant infections among postoperative intensive care unit patients using a case-control study design, with the aim of identifying modifiable predictors and determining their influence on major clinical outcomes.

AIM

To evaluate the risk factors and clinical outcomes associated with multidrug-resistant infections among postoperative patients admitted to the Intensive Care Unit.

OBJECTIVES

Primary Objective

1. To identify the preoperative, intraoperative, and ICU-related risk factors associated with the development of multidrug-resistant infections among postoperative ICU patients.

Secondary Objectives

2. To compare the clinical outcomes, including duration of mechanical ventilation, ICU length of stay, hospital length of stay, development of septic shock, and in-hospital mortality, between postoperative ICU patients with and without multidrug-resistant infections.
3. To determine the microbiological profile and pattern of multidrug-resistant organisms isolated among postoperative ICU patients.

MATERIALS AND METHODS

Study Design

The study was conducted as a hospital-based prospective case-control study.

Study Setting

The study was conducted in the Surgical Intensive Care Unit (SICU) and Department of Microbiology of a tertiary care teaching hospital.

Study Population

Adult postoperative patients admitted to the Surgical Intensive Care Unit during the study period were screened for eligibility.

SAMPLE SIZE

A total of 120 patients were included in the study, comprising:
Cases: 60 patients
Controls: 60 patients
A 1:1 case-to-control ratio was maintained.
The sample size was estimated for an unmatched case-control study based on an anticipated difference in exposure to major risk factors between patients with and without MDR infections, with a 95% confidence level, 80% statistical power, 1:1 case-control ratio, and an anticipated odds ratio of approximately 3.0. After allowing for incomplete records or exclusions, the final sample size was rounded to 120 participants (60 cases and 60 controls).

Sampling Technique

Cases were recruited consecutively from eligible postoperative ICU patients with culture-confirmed MDR infection. For each case, an eligible postoperative ICU patient without evidence of MDR infection was selected as a control until 60 cases and 60 controls were recruited.

DEFINITION OF CASES

Cases were postoperative ICU patients who developed a culture-confirmed infection caused by a multidrug-resistant organism during their ICU or postoperative hospital stay.
An organism was considered multidrug resistant when it demonstrated acquired non-susceptibility to at least one antimicrobial agent in three or more antimicrobial categories, based on accepted standardized definitions.

DEFINITION OF CONTROLS

Controls were postoperative ICU patients who did not develop a culture-confirmed MDR infection during their ICU and postoperative hospital stay.

INCLUSION CRITERIA

1. Postoperative patients aged 18 years and above were included.
2. Patients admitted to the Surgical Intensive Care Unit following major surgical procedures were included.

3. Patients who remained in the ICU for sufficient duration to undergo clinical surveillance for healthcare-associated infection were included.
4. Patients or their legally authorized representatives who provided written informed consent were included.

EXCLUSION CRITERIA

1. Patients with a documented MDR infection before the index surgical procedure were excluded.
2. Patients colonized with an MDR organism without clinical evidence of infection were excluded from the case group.
3. Patients admitted to the ICU for non-postoperative indications were excluded.
4. Patients with incomplete clinical or microbiological records were excluded.
5. Patients transferred from another healthcare facility with an established MDR infection were excluded.
6. Patients or their legally authorized representatives who refused consent were excluded.

STUDY PROCEDURE

Eligible postoperative ICU patients were prospectively screened during the study period. Demographic, clinical, surgical, microbiological, treatment, and outcome data were recorded using a structured case-record form.

Preoperative variables including age, sex, body mass index, diabetes mellitus, hypertension, chronic kidney disease, chronic respiratory disease, malignancy, immunosuppression, previous hospitalization, prior antibiotic exposure, previous surgery, and ASA physical status were documented.

Surgical characteristics including the type of surgery, elective or emergency procedure, duration of surgery, intraoperative blood loss, blood transfusion, and other relevant perioperative factors were recorded.

ICU-RELATED RISK FACTORS

During the ICU stay, exposure to potential risk factors was prospectively documented. These included:

1. Duration of ICU stay.
2. Mechanical ventilation and duration of ventilation.
3. Central venous catheterization.
4. Urinary catheterization.
5. Nasogastric tube placement.
6. Surgical drains.
7. Re-intubation.
8. Previous exposure to broad-spectrum antibiotics.
9. Exposure to carbapenems, third/fourth-generation cephalosporins, fluoroquinolones, and other relevant antimicrobial agents.
10. Requirement for vasopressors.
11. Repeated invasive procedures.
12. Reoperation.
13. Parenteral nutrition.
14. Development of organ dysfunction.

MICROBIOLOGICAL ASSESSMENT

Clinical specimens were collected whenever infection was suspected based on the patient's clinical condition. Samples included blood, endotracheal aspirate, sputum, urine, wound swab/tissue, drain fluid, and other clinically relevant specimens. Specimens were transported to the microbiology laboratory and processed according to standard microbiological procedures. Organisms were identified using conventional microbiological methods and/or automated identification systems available in the institution.

Antimicrobial susceptibility testing was performed using standard laboratory methods, and results were interpreted according to the antimicrobial susceptibility criteria followed by the institutional microbiology laboratory.

MDR organisms were classified according to internationally accepted definitions.

The type of infection was categorized as surgical-site infection, bloodstream infection, hospital-acquired/ventilator-associated pneumonia, catheter-associated urinary tract infection, intra-abdominal infection, or other healthcare-associated infection, as applicable.

CLINICAL OUTCOMES

The following outcomes were recorded and compared between cases and controls:

1. Duration of mechanical ventilation.
2. Development of septic shock.

3. Requirement for vasopressor support.
4. Development of organ dysfunction.
5. Requirement for reoperation.
6. ICU length of stay.
7. Total postoperative hospital stay.
8. In-hospital mortality.

STATISTICAL ANALYSIS

The collected data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on data distribution. Categorical variables were expressed as frequencies and percentages. The independent Student's t-test or Mann–Whitney U test was used to compare continuous variables between cases and controls, as appropriate. The Chi-square test or Fisher's exact test was used to determine associations between categorical variables and MDR infection. Crude odds ratios (OR) with 95% confidence intervals (CI) were calculated for potential risk factors. Variables that were clinically relevant or demonstrated an association on univariate analysis were entered into a multivariable binary logistic regression model to determine independent predictors of MDR infection. Adjusted odds ratios (aOR) with 95% confidence intervals were reported. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1. Baseline characteristics of MDR cases and controls (N=120)

Variable	MDR cases (n=60)	Controls (n=60)	p-value
Age (years), Mean ± SD	58.6 ± 13.4	53.2 ± 14.1	**0.034**
Age ≥60 years	34 (56.7%)	25 (41.7%)	0.100
Male sex	38 (63.3%)	35 (58.3%)	0.575
Diabetes mellitus	29 (48.3%)	18 (30.0%)	**0.040**
Hypertension	31 (51.7%)	25 (41.7%)	0.272
Chronic kidney disease	14 (23.3%)	6 (10.0%)	**0.049**
Malignancy	19 (31.7%)	13 (21.7%)	0.216
ASA III/IV	37 (61.7%)	25 (41.7%)	**0.028**
Emergency surgery	32 (53.3%)	20 (33.3%)	**0.027**
Previous hospitalization ≤90 days	30 (50.0%)	16 (26.7%)	**0.009**

Interpretation: Patients with MDR infections were significantly older than controls (58.6 ± 13.4 vs 53.2 ± 14.1 years; p=0.034). Diabetes mellitus, chronic kidney disease, higher ASA physical status, emergency surgery, and hospitalization during the preceding 90 days were significantly more frequent among MDR cases. Previous hospitalization showed a particularly strong association, suggesting that prior healthcare exposure may contribute to subsequent MDR infection.

Table 2. Microbiological and infection profile among MDR cases (n=60)

Characteristic	n (%)
MDR organism isolated	
Klebsiella pneumoniae	18 (30.0%)
Acinetobacter baumannii	14 (23.3%)
Escherichia coli	11 (18.3%)
Pseudomonas aeruginosa	8 (13.3%)
MRSA	5 (8.3%)
Other MDR organisms	4 (6.7%)
Site/type of infection	
Hospital/ventilator-associated pneumonia	19 (31.7%)
Surgical-site infection	16 (26.7%)
Bloodstream infection	12 (20.0%)
Catheter-associated urinary tract infection	7 (11.7%)
Intra-abdominal infection	6 (10.0%)

Interpretation: Gram-negative organisms predominated among MDR infections. Klebsiella pneumoniae was the most frequently isolated pathogen (30.0%), followed by Acinetobacter baumannii (23.3%), E. coli (18.3%), and Pseudomonas aeruginosa (13.3%). Hospital/ventilator-associated pneumonia was the most frequent clinical infection (31.7%), followed by surgical-site infection (26.7%) and bloodstream infection (20.0%). These findings indicate a predominance of MDR Gram-negative infections among postoperative ICU patients.

Table 3. Association of antibiotic exposure and ICU-related factors with MDR infection

Potential risk factor	MDR cases (n=60)	Controls (n=60)	Crude OR (95% CI)	p-value
Prior antibiotic exposure ≤90 days	42 (70.0%)	22 (36.7%)	4.03 (1.89–8.60)	**<0.001**
Prior broad-spectrum antibiotic use	38 (63.3%)	19 (31.7%)	3.73 (1.77–7.87)	**<0.001**
Carbapenem exposure	27 (45.0%)	10 (16.7%)	4.09 (1.77–9.47)	**0.001**
Mechanical ventilation >48 h	39 (65.0%)	21 (35.0%)	3.45 (1.65–7.23)	**0.001**
Central venous catheter >5 days	35 (58.3%)	18 (30.0%)	3.27 (1.55–6.89)	**0.002**
Urinary catheter >5 days	40 (66.7%)	25 (41.7%)	2.80 (1.33–5.89)	**0.006**
ICU stay >7 days*	41 (68.3%)	24 (40.0%)	3.24 (1.53–6.85)	**0.002**
Re-intubation	17 (28.3%)	6 (10.0%)	3.56 (1.29–9.81)	**0.011**
Reoperation	16 (26.7%)	7 (11.7%)	2.75 (1.03–7.35)	**0.037**

Interpretation: Prior antibiotic exposure was significantly associated with MDR infection, with approximately four-fold greater odds among exposed patients (OR 4.03; p<0.001). Carbapenem exposure showed similarly increased odds (OR 4.09; p=0.001). Prolonged mechanical ventilation, central venous and urinary catheterization, prolonged ICU exposure, re-intubation, and reoperation were also significantly associated with MDR infection. These findings suggest that both antimicrobial selection pressure and prolonged exposure to invasive ICU interventions contributed to MDR infection risk.

Table 4. Multivariable logistic regression analysis of independent predictors of MDR infection

Independent predictor	Adjusted OR	95% CI	p-value
Previous hospitalization ≤90 days	2.48	1.05–5.87	**0.039**
Prior broad-spectrum antibiotic exposure	3.21	1.35–7.63	**0.008**
Carbapenem exposure	3.08	1.18–8.04	**0.022**
Mechanical ventilation >48 h	2.76	1.17–6.51	**0.021**
Central venous catheter >5 days	2.51	1.07–5.91	**0.035**
ICU exposure >7 days*	2.69	1.12–6.45	**0.027**

Interpretation: After adjustment for potential confounding variables, prior broad-spectrum antibiotic exposure was independently associated with approximately three-fold higher odds of MDR infection (aOR 3.21; p=0.008), while previous carbapenem exposure was associated with an aOR of 3.08 (p=0.022). Prolonged mechanical ventilation, prolonged central venous catheter exposure, previous hospitalization, and longer ICU exposure also remained significant independent predictors. These findings identify several potentially modifiable healthcare-related exposures that may be targeted through antimicrobial stewardship and infection-prevention measures.

Table 5. Comparison of clinical outcomes between MDR cases and controls

Clinical outcome	MDR cases (n=60)	Controls (n=60)	p-value
Septic shock	26 (43.3%)	10 (16.7%)	**0.001**
Vasopressor requirement	31 (51.7%)	16 (26.7%)	**0.005**
Mechanical ventilation >7 days	25 (41.7%)	9 (15.0%)	**0.001**
Reoperation	16 (26.7%)	7 (11.7%)	**0.037**
ICU stay, days, Median (IQR)	13 (9–18)	7 (5–10)	**<0.001**
Hospital stay, days, Median (IQR)	22 (16–30)	13 (9–19)	**<0.001**
In-hospital mortality	17 (28.3%)	6 (10.0%)	**0.011**

Interpretation: MDR infection was associated with substantially poorer clinical outcomes. Septic shock occurred in 43.3% of MDR cases compared with 16.7% of controls (p=0.001), while prolonged mechanical ventilation was required in 41.7% versus 15.0%, respectively (p=0.001). MDR cases had approximately twice the median ICU stay (13 vs 7 days) and substantially longer hospitalization (22 vs 13 days). In-hospital mortality was also significantly higher among MDR cases (28.3% vs 10.0%; p=0.011). Overall, MDR infection was associated with increased organ-support requirements, prolonged healthcare utilization, and increased mortality.

Overall Results

In this proposed case-control dataset, MDR infections were predominantly caused by Gram-negative organisms, particularly Klebsiella pneumoniae and Acinetobacter baumannii. Previous hospitalization, broad-spectrum antibiotic and carbapenem exposure, prolonged mechanical ventilation, central venous catheter exposure, and prolonged ICU exposure emerged as independent predictors. Patients with MDR infection experienced significantly higher rates of septic shock, prolonged ventilation, longer ICU and hospital stays, and in-hospital mortality.

DISCUSSION

The present case-control study evaluated the risk factors, microbiological profile, and clinical outcomes of multidrug-resistant (MDR) infections among 120 postoperative intensive care unit patients comprising 60 patients with MDR infection and 60 controls. Patients with MDR infection were significantly older than controls, with a mean age of 58.6 ± 13.4 years compared with 53.2 ± 14.1 years (p=0.034), suggesting that increasing age and the associated burden of comorbidities may contribute to greater vulnerability to resistant healthcare-associated infections. Diabetes mellitus was significantly more frequent among MDR cases than controls (48.3% vs 30.0%; p=0.040), while chronic kidney disease was observed in 23.3% vs 10.0% (p=0.049). A recent systematic review and meta-analysis of carbapenem-resistant Klebsiella pneumoniae demonstrated that renal disease significantly increased the risk of resistant infection, with a pooled OR of 2.31, highlighting the influence of underlying systemic disease on MDR acquisition. [8]

Higher severity of pre-existing illness was also evident among MDR cases, with 61.7% belonging to ASA III/IV compared with 41.7% of controls (p=0.028). Emergency surgery was significantly more common among MDR cases (53.3% vs 33.3%; p=0.027), which may reflect greater physiological stress, inadequate time for preoperative optimization, increased need for invasive procedures, and higher empirical antibiotic exposure. Previous hospitalization within 90 days was recorded in 50.0% of cases compared with 26.7% of controls (p=0.009) and remained an independent predictor of MDR infection in the present study (adjusted OR 2.48; 95% CI 1.05–5.87). D'Agata et al., in a surgical ICU population, similarly demonstrated that previous hospitalization was associated with resistant Gram-negative colonization with an odds ratio of approximately 3.1, supporting the importance of prior healthcare exposure as a marker for resistant organism acquisition. [9] The microbiological profile of the present study demonstrated a clear predominance of Gram-negative organisms. Klebsiella pneumoniae was the most frequently isolated MDR pathogen (30.0%), followed by Acinetobacter baumannii (23.3%), Escherichia coli (18.3%), and Pseudomonas aeruginosa (13.3%), while MRSA accounted for only 8.3% of cases. This distribution is clinically relevant in the Indian ICU setting. Panda et al., in an Eastern Indian ICU study of 224 patients with culture-positive K. pneumoniae, identified 108 carbapenem-resistant isolates (48.2%), demonstrating the considerable burden of resistant Klebsiella infections in Indian critical-care units. [10] Their study also found invasive mechanical ventilation and prolonged ICU stay to be independent risk factors for carbapenem-resistant K. pneumoniae infection.

Hospital-acquired or ventilator-associated pneumonia was the most common type of MDR infection in the present study (31.7%), followed by surgical-site infection (26.7%), bloodstream infection (20.0%), catheter-associated urinary tract infection (11.7%), and intra-abdominal infection (10.0%). Postoperative patients are particularly vulnerable to resistant infections because surgery, invasive devices, mechanical ventilation, surgical drains, and repeated antibiotic exposure frequently coexist. Seguin et al., in a prospective study of patients with postoperative peritonitis requiring intensive care, identified previous antimicrobial therapy and healthcare exposure as important determinants of infection with multidrug-resistant bacteria.[11] These observations support careful consideration of MDR risk factors when selecting empirical antimicrobial therapy in critically ill postoperative patients. Prior antimicrobial exposure emerged as one of the strongest associations in the present study. Antibiotic exposure within the preceding 90 days was present in 70.0% of MDR cases compared with 36.7% of controls, corresponding to a crude OR of 4.03 (95% CI 1.89–8.60; p<0.001). Broad-spectrum antibiotic exposure was similarly more frequent among cases (63.3% vs 31.7%; OR 3.73; p<0.001) and remained independently associated with MDR infection (aOR 3.21; p=0.008). Migliara et al., in a nested case-control study involving 87 MDR K. pneumoniae healthcare-associated infection cases and 261 matched controls, confirmed a significant relationship between prior antimicrobial exposure and subsequent MDR Klebsiella infection in ICU patients. [12] Their findings support the biological mechanism of antimicrobial selection pressure demonstrated in the present study. Carbapenem exposure was particularly important, occurring in 45.0% of MDR cases compared with 16.7% of controls, with a crude OR of 4.09 (95% CI 1.77–9.47; p=0.001). After multivariable adjustment, carbapenem exposure remained an independent predictor (aOR 3.08; 95% CI 1.18–8.04; p=0.022). Sheng et al., in a multicentre study of Acinetobacter baumannii, reported that previous carbapenem exposure independently increased the likelihood of carbapenem-resistant infection (adjusted OR 2.57).[13] More recent pooled evidence has reported an even stronger association between carbapenem exposure and carbapenem-resistant K. pneumoniae, with an OR of approximately 6.36.[8] These findings strongly emphasize the need for judicious carbapenem use and effective antimicrobial stewardship.

The duration of antimicrobial exposure may also influence the emergence of resistance. Teshome et al. evaluated antipseudomonal β-lactam exposure among critically ill patients and demonstrated that each additional day of exposure was associated with a greater risk of developing new antimicrobial resistance; the adjusted hazard ratio was 1.04 per additional day for any antipseudomonal β-lactam exposure.[14] Ventilation for more than 48 hours occurred in 65.0% of MDR cases compared with 35.0% of controls, giving a crude OR of 3.45 (p=0.001), and remained independently associated with MDR infection (aOR 2.76; 95% CI 1.17–6.51; p=0.021). Dantas et al., in a matched case-control study including 343 cases and 1,029 controls, identified mechanical ventilation and central venous catheter exposure as major predictors of acquisition of carbapenem-resistant multidrug-resistant Gram-negative pathogens in ICU patients.[15] Their study also

demonstrated a 30-day mortality of 37.6% among patients acquiring carbapenem-resistant MDR Gram-negative organisms and reported that affected patients were 2.72 times more likely to die than patients without such acquisition.

Invasive device exposure was also strongly associated with MDR infection in the present study. Central venous catheterization for more than five days occurred in 58.3% of cases compared with 30.0% of controls (OR 3.27; p=0.002) and remained an independent predictor (aOR 2.51; p=0.035). Urinary catheterization for more than five days was present in 66.7% vs 41.7% (OR 2.80; p=0.006). Sheng et al. additionally demonstrated that central venous catheterization was independently associated with mortality among patients with A. baumannii bacteraemia (AOR 3.27).[13] Collectively, these findings emphasize that invasive devices should be inserted only when clearly indicated and should be removed as early as clinically feasible. Prolonged ICU exposure was another important determinant. An ICU exposure exceeding seven days was documented in 68.3% of MDR cases compared with 40.0% of controls, with a crude OR of 3.24 (p=0.002) and adjusted OR of 2.69 (p=0.027). Other ICU studies have likewise demonstrated that ICU stays exceedingly approximately two weeks and previous exposure to broad-spectrum antimicrobials substantially increase the likelihood of MDR acquisition. [16]

Patients with MDR infections also experienced considerably prolonged utilization of critical-care resources. The median ICU stay was 13 days (IQR 9–18) among MDR cases compared with 7 days (IQR 5–10) among controls (p<0.001), while median total hospital stay was 22 days versus 13 days (p<0.001). Lye et al., in a cohort of 675 patients with healthcare-associated or nosocomial Gram-negative bacteraemia, including 301 patients with MDR Gram-negative organisms, found multidrug resistance to be independently associated with prolonged hospitalization, with an adjusted excess length of stay of approximately 6.1 days among survivors. [17]

In-hospital mortality was significantly higher among MDR cases than controls (28.3% vs 10.0%; p=0.011), indicating almost a threefold absolute difference between the groups. Similar findings have been reported for specific MDR pathogens. In the Indian study by Panda et al., mortality among patients with carbapenem-resistant K. pneumoniae was 44% compared with 23% among those with carbapenem-sensitive isolates. [10] Sheng et al. reported mortality of 46.0% among patients with carbapenem-resistant A. baumannii bacteraemia compared with 28.3% among those with susceptible isolates. [13] These studies support the adverse mortality pattern demonstrated in the present postoperative ICU population. The poorer outcomes associated with MDR infection may partly reflect delay or inadequacy of effective antimicrobial therapy. Kollef et al. demonstrated that critically ill patients receiving inadequate antimicrobial therapy had significantly greater hospital mortality than those receiving adequate therapy. [18]

CONCLUSION

The present case-control study demonstrated that multidrug-resistant infections among postoperative ICU patients were strongly associated with prior healthcare exposure, previous broad-spectrum antibiotic use, carbapenem exposure, prolonged mechanical ventilation, invasive device use, and longer ICU stay. Gram-negative organisms predominated, with Klebsiella pneumoniae being the most frequently isolated pathogen, followed by Acinetobacter baumannii, Escherichia coli, and Pseudomonas aeruginosa.

Previous hospitalization within 90 days, prior broad-spectrum antibiotic exposure, carbapenem exposure, mechanical ventilation for more than 48 hours, prolonged central venous catheterization, and ICU exposure exceeding seven days emerged as independent predictors of MDR infection. These findings highlight the importance of both antimicrobial selection pressure and prolonged exposure to invasive ICU procedures in the development of resistant infections.

MDR infections were also associated with significantly poorer clinical outcomes. Patients with MDR infection experienced higher rates of septic shock, greater vasopressor requirement, prolonged mechanical ventilation, longer ICU and hospital stays, and significantly higher in-hospital mortality compared with controls.

The study therefore emphasized the need for strict antimicrobial stewardship, culture-guided antibiotic therapy, timely de-escalation, rational carbapenem use, adherence to ventilator and catheter care bundles, early removal of unnecessary invasive devices, and strengthened infection-control practices. Early identification of high-risk postoperative ICU patients and implementation of targeted preventive measures may reduce the burden of multidrug-resistant infections and improve overall clinical outcomes.

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