



Detection of Multidrug-Resistant *Klebsiella pneumoniae* in Intensive Care Units

Muhammad Ahsan Razza¹, Arebaa Kholid², Syeed Hamza Naqvi^{3,4}

¹Department of Microbiology, University of Health Sciences Lahore, Lahore, Pakistan

²Department of Infectious Diseases, Aga Khan University, Karachi, Pakistan

³Department of Clinical Laboratory Sciences, Dow University of Health Sciences, Karachi, Pakistan

⁴Department of Public Health, Khyber Medical University, Peshawar, Pakistan

*Corresponding Author: Muhammad Ahsan Razza

E-mail: areeab654@gmail.com

Article Info

Article History:

Received: 12 May 2026

Revised: 18 June 2026

Accepted: 7 July 2026

Keywords:

Antimicrobial
Resistance, Carbapenem
Resistance, Healthcare-
Associated Infection,
Intensive Care Unit,
Klebsiella Pneumoniae,
Multidrug-Resistant
Bacteria

Abstract

This study investigates the detection of multidrug-resistant (MDR) *Klebsiella pneumoniae* among Intensive Care Unit patients in tertiary healthcare hospitals in Pakistan. The research aims to identify the prevalence, resistance patterns, and clinical factors associated with MDR *Klebsiella pneumoniae* infections in ICU settings. A quantitative cross-sectional design was employed using microbiological culture and antimicrobial susceptibility testing based on Clinical and Laboratory Standards Institute guidelines. Clinical specimens, including tracheal aspirates, blood, urine, sputum, and wound swabs, were collected from ICU patients with suspected bacterial infections. The findings revealed a high prevalence of MDR *Klebsiella pneumoniae*, with substantial resistance against third-generation cephalosporins, fluoroquinolones, aminoglycosides, and carbapenems. Prolonged ICU hospitalization, mechanical ventilation, urinary catheter use, and prior antibiotic exposure were significantly associated with MDR occurrence. The study contributes to antimicrobial resistance literature by providing updated epidemiological evidence and practical implications for strengthening infection control strategies, antimicrobial stewardship programs, and hospital surveillance systems in developing healthcare settings.

INTRODUCTION

AIR is one of the biggest public health threats of the 21st century. Multidrug resistant (MDR) bacterial pathogens are increasingly a major challenge in the management of infections, especially in the hospital setting where vulnerable patients are undergoing invasive medical procedures and long courses of antibiotic therapy (Alara & Alara, 2024; Kumar et al., 2024; Onorato et al., 2022). *Klebsiella pneumoniae* is particularly problematic among the resistant pathogens because of its tendency to acquire resistance genes, as well as its ability to cause severe nosocomial infections, such as pneumonia, urinary tract infection (UTI), bloodstream infection (BSI), and sepsis.

Carbapenem-resistant *Klebsiella pneumoniae* is a priority pathogen of the World Health Organization due to its significant role in global morbidity and mortality in hospital settings, and the urgent need for new antimicrobial interventions (Song et al., 2025; Rahmat Ullah et al., 2024; Ju et al., 2025; Li et al., 2025; Mohammed et al., 2023).

ICUs are one of the most vulnerable settings for the emergence and spread of MDR pathogens (Woźniak et al., 2024; Coşovanu et al., 2026; Darouei et al., 2025). Patients requiring mechanical ventilation, central venous catheters, urinary catheters, and extended hospitalization are often very sick and are at risk for HAI. Furthermore, the broad-spectrum and empirical use of antibiotics in the ICU facilitates the selection of bacteria with resistance (Micek et al., 2025; Ashraf, 2025; van der Schalk et al., 2026). It has been previously demonstrated that *Klebsiella pneumoniae* has the ability to rapidly spread across healthcare facilities through horizontal gene transfer mechanisms, thereby disseminating extended-spectrum beta-lactamase (ESBL) and carbapenemase-producing strains. This has led to the detection and monitoring of MDR *Klebsiella pneumoniae* in ICUs coming into the spotlight for infection prevention and antimicrobial stewardship programs (Geremia et al., 2024; Wushouer et al., 2025; Muresu et al., 2023; Ge et al., 2026; Chi et al., 2022).

Antimicrobial resistance has significantly increased in recent years in developing countries, driven by sub-optimal infection control, availability of antibiotics without restriction, weak surveillance of antimicrobial resistance in laboratories and lack of antimicrobial stewardship policies. Pakistan has been reported as one of the countries which are facing a major problem with the management of antibiotic resistant infections (Mirha et al., 2024; Arshad et al., 2022). Despite various efforts and initiatives, the healthcare system in Pakistan remains grappling with issues including: Hospital based several epidemiological reports reveal the growing trend of MDR gram-negative bacterial infections particularly in hospitals where critically sick individuals are kept in critical care units (ICU). All these conditions favor the growth and spread of MDR *Klebsiella pneumoniae*.

The epidemiology and resistance patterns of *Klebsiella pneumoniae* have been well studied abroad and within a hospital setting. In China, India, Turkey and Middle Eastern countries, carbapenem-resistant and ESBL-producing *Klebsiella pneumoniae* (CR-EP-KP) were isolated from ICUs with alarming increases. The delayed detection of pathogens and the use of the wrong antibiotic is an important factor in treatment failures and deaths, as these studies highlighted. In addition, the genetic sequencing of resistant bacteria often showed the presence of genes like blaKPC, blaNDM, and blaOXA-48, which help the bacteria resist last-resort antibiotics (Osei Sekyere et al., 2024; Noori Goodarzi et al., 2026). These studies have offered much information on the resistance trends worldwide, but there are a number of differences between countries and hospitals in terms of antibiotic policies, infrastructure and infection control measures that mean there are different patterns of antimicrobial resistance.

In Pakistan, few studies have been conducted to demonstrate the existence of MDR gram-negative pathogens in tertiary hospitals. In the Pakistani context, a few studies have been reported, which demonstrated the presence of MDR gram negative pathogens in tertiary hospitals. Most of the studies being conducted, however, focus on general antimicrobial resistance surveillance and do not specifically address the *Klebsiella pneumoniae* infections in ICUs (Sandu et al., 2026; Kilinc, 2025). A few studies focused mainly on antibiotic resistance patterns without considering clinical and epidemiological aspects regarding the dynamics of transmission in the ICU. Moreover, many of the earlier studies relied on relatively small samples and/or the data from a single hospital, thus reducing the generalizability of the results. Very

little is known about the prevalence and the detection pattern of MDR *Klebsiella pneumoniae* in the post-pandemic era when the use of antibiotics have increased in the ICUs of Pakistan. This suggests a compelling need for research to explore newer and context-specific evidence of detection of MDR *Klebsiella pneumoniae* in Pakistani ICUs.

The increasing prevalence of MDR *Klebsiella pneumoniae* has grave consequences for the health care system in Pakistan. Resistant infections are linked to length of hospital stay, treatment expenses, morbidity and mortality rates in critically ill. Furthermore, resistance may not be identified for a period, which could compromise treatment decisions and contribute to outbreaks in the hospital. Surveillance and early detection are therefore crucial to enhance infection control (Alatawi et al., 2025) and optimal antibiotic use. Local resistance patterns are important from a public health standpoint for the design of specific antimicrobial stewardship policies and improvement of hospital infection prevention policies. Therefore, clinical and policy relevance of research specifically focusing on detection of MDR *Klebsiella pneumoniae* associated with the ICU is noteworthy in the Pakistani healthcare system.

In recent years, the literature on antimicrobial resistance has increasingly highlighted the importance of new technologies for rapid microbiological detection, resistance profiling, and evidence-based approaches to infection control. In recent years, molecular diagnostics and new susceptibility testing techniques have been used to more accurately and efficiently identify resistant pathogens. However, their use in developing healthcare systems is not consistent, such as Pakistan (Shah et al., 2024). Despite the existing literature, there is still a lack of comprehensive empirical evidence of the prevalence and detection characteristics of MDR *Klebsiella pneumoniae* in Pakistani hospitals. In addition, there is a scarcity of studies investigating the contribution of clinical conditions observed in the ICU to the resistance persistence and dissemination in hospital environment.

In this context, the idea of the present study was formed to analyze the detection of MDR (Multidrug Resistant) KP (*Klebsiella pneumoniae*) in the ICUs of Pakistan and to determine the pattern of drug resistance and prevalence of MDR KP among the patients of ICUs. The novelty of this study is the exclusive focus on MDR *Klebsiella pneumoniae* in the current context of Pakistani healthcare system along with the emerging antimicrobial resistance issues after the pandemic. This study offers a more in-depth investigation of the detection of MDR *Klebsiella pneumoniae*, as opposed to previous studies that focused primarily on general patterns of bacterial resistance. The results would be useful in theory for the existing literature about antimicrobial resistance in developing countries and would be helpful for practical application in enhancing infection control policies, antibiotic stewardship programs and hospital surveillance systems in Pakistan.

METHODS

Research Design

This study employed a quantitative cross-sectional research design to investigate the detection and prevalence of multidrug-resistant (MDR) *Klebsiella pneumoniae* among patients admitted to Intensive Care Units (ICUs) in tertiary healthcare hospitals in Pakistan. A cross-sectional design was considered appropriate because it enables the systematic identification of bacterial resistance patterns within a defined period while providing an empirical overview of the current antimicrobial resistance situation in ICU settings. Quantitative laboratory-based approaches are widely used in antimicrobial resistance surveillance studies due to their ability to generate measurable and comparable microbiological data. The study integrated microbiological examination with epidemiological analysis to evaluate the occurrence of MDR *Klebsiella pneumoniae* isolates and their antibiotic susceptibility profiles.

Research Setting and Context

The research was conducted in several tertiary-care hospitals equipped with ICU facilities in major urban regions of Pakistan. These hospitals were selected because they represent referral healthcare centers with high patient admissions, extensive antibiotic utilization, and increased risks of healthcare-associated infections. ICU wards were specifically chosen as the primary research setting due to the elevated vulnerability of critically ill patients to nosocomial infections caused by resistant gram-negative bacteria. Data collection was conducted over a six-month period from hospitalized patients who met the inclusion criteria. The selected healthcare institutions routinely perform microbiological culture and antimicrobial susceptibility testing as part of their infection control and clinical diagnostic procedures.

Sample and Data Collection Procedures

The study utilized purposive sampling to obtain clinical specimens from ICU patients suspected of bacterial infections. Samples included blood, sputum, urine, wound swabs, and tracheal aspirates collected under sterile clinical procedures. Patients included in the study were those admitted to ICUs for more than 48 hours and who demonstrated clinical signs of infection during hospitalization. Patients with incomplete microbiological records or contaminated specimens were excluded from the analysis.

Bacterial isolation and identification procedures were conducted using standard microbiological techniques. Clinical specimens were cultured on selective media, followed by biochemical identification tests to confirm the presence of *Klebsiella pneumoniae*. Antimicrobial susceptibility testing was subsequently performed using the Kirby–Bauer disk diffusion method in accordance with the guidelines established by the Clinical and Laboratory Standards Institute (CLSI). Antibiotics tested included carbapenems, cephalosporins, aminoglycosides, fluoroquinolones, and beta-lactam combination agents commonly prescribed in ICU settings. Isolates demonstrating resistance to three or more antimicrobial classes were categorized as multidrug-resistant strains. Similar laboratory procedures have been widely applied in previous antimicrobial resistance studies due to their reliability and diagnostic consistency.

Table 1. Categories of Clinical Specimens and Laboratory Examination Procedures

Clinical Specimen	Laboratory Procedure	Purpose
Blood Samples	Blood culture and susceptibility testing	Detection of bloodstream infection
Sputum Samples	Culture and bacterial identification	Detection of respiratory infection
Urine Samples	Urine culture and AST	Detection of urinary tract infection
Wound Swabs	Culture examination	Detection of wound-associated infection
Tracheal Aspirates	Gram staining and culture	Detection of ventilator-associated infection

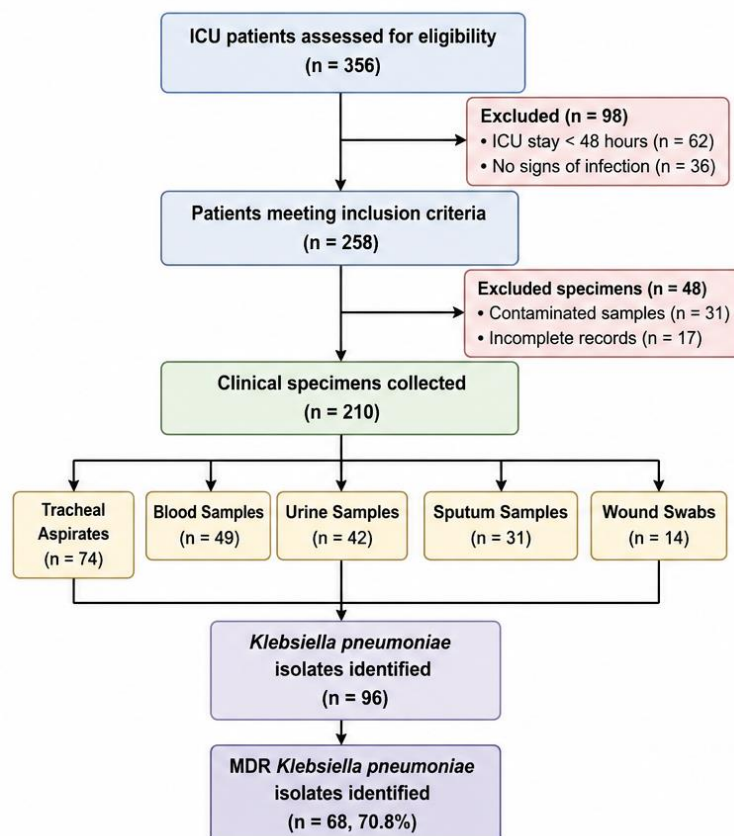


Figure 1. Flowchart of ICU Patient Selection and MDR *Klebsiella pneumoniae* Detection

Source: Research data processed by the authors, 2026

The sample selection process and inclusion criteria are illustrated in Figure 1.

Data Analysis

The collected data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics were applied to determine the prevalence and frequency distribution of MDR *Klebsiella pneumoniae* isolates across different specimen types and antibiotic categories. Inferential statistical analysis, including chi-square tests, was conducted to evaluate associations between clinical variables and the occurrence of MDR isolates. Statistical significance was determined at a confidence level of 95% with a p-value threshold of less than 0.05. The analysis was performed using Statistical Package for the Social Sciences (SPSS) software to ensure systematic and accurate data processing.

Validity and Reliability

To ensure the validity and reliability of the study findings, standardized laboratory protocols and internationally recognized antimicrobial susceptibility guidelines were consistently implemented throughout the research process. The use of CLSI standards enhanced the methodological validity of bacterial identification and resistance classification. In addition, all microbiological examinations were conducted by trained laboratory personnel under controlled clinical laboratory conditions to minimize procedural bias and measurement errors. Reliability was further strengthened through repeated verification of bacterial isolates and double-checking of susceptibility test interpretations. The study also adhered to ethical standards for clinical research by maintaining patient confidentiality and obtaining institutional approval prior to data collection.

RESULTS AND DISCUSSION

This section presents the empirical findings regarding the detection of multidrug-resistant (MDR) *Klebsiella pneumoniae* among Intensive Care Unit (ICU) patients in tertiary healthcare hospitals in Pakistan. The results are organized systematically into several analytical components, including patient demographic characteristics, distribution of clinical specimens, prevalence of MDR *Klebsiella pneumoniae*, antibiotic resistance profiles, and the association between clinical variables and MDR occurrence. The presentation of findings aims to provide a comprehensive overview of resistance patterns and the epidemiological characteristics of ICU-associated *Klebsiella pneumoniae* infections.

Demographic Characteristics of Patients

A total of 210 ICU patients who met the inclusion criteria were included in this study. Clinical specimens were collected from patients admitted to ICU wards for more than 48 hours and suspected of bacterial infection. The demographic distribution of patients is presented in Table 2.

Table 2. Demographic Characteristics of ICU Patients

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	128	61.0
	Female	82	39.0
Age Group	18–35 years	39	18.6
	36–50 years	61	29.0
	51–65 years	72	34.3
	>65 years	38	18.1
ICU Stay Duration	2–5 days	56	26.7
	6–10 days	89	42.4
	>10 days	65	31.0

Source: Primary laboratory and hospital data processed by the researchers, 2026

Table 2 demonstrates that male patients represented the majority of ICU admissions, accounting for 61.0% of the total sample. Patients aged 51–65 years constituted the largest age group, indicating that middle-aged and older adults were more vulnerable to severe infections requiring intensive care management. In addition, prolonged ICU hospitalization was commonly observed, with 42.4% of patients remaining in ICU wards for 6–10 days. Extended hospitalization is clinically important because prolonged exposure to invasive procedures and antibiotics may increase susceptibility to MDR bacterial infections. The findings also revealed that older patients experienced higher frequencies of culture-confirmed *Klebsiella pneumoniae* infections compared to younger groups. This trend suggests that age-related immune decline and chronic comorbidities may contribute to increased infection risk among critically ill individuals.

Distribution of Clinical Specimens

Clinical specimens were collected from different infection sites to identify the presence of *Klebsiella pneumoniae* isolates among ICU patients. The distribution of specimen categories is summarized in Table 3.

Table 3. Distribution of Clinical Specimens

Specimen Type	Frequency (n)	Percentage (%)
Tracheal Aspirates	74	35.2
Blood Samples	49	23.3
Urine Samples	42	20.0
Sputum Samples	31	14.8

Wound Swabs	14	6.7
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Source: Primary microbiological laboratory records, 2026

As shown in Table 3, tracheal aspirates represented the most frequently collected specimens, accounting for 35.2% of the total samples. This finding reflects the high prevalence of ventilator-associated respiratory infections among ICU patients receiving mechanical ventilation support. Blood cultures constituted the second largest specimen category, suggesting substantial occurrence of bloodstream infections in critically ill patients.

Urine samples also contributed significantly to bacterial detection, indicating the presence of catheter-associated urinary tract infections within ICU environments. Meanwhile, wound swab specimens represented the smallest proportion because only a limited number of ICU patients exhibited surgical or traumatic wound complications during hospitalization. The predominance of respiratory-related specimens emphasizes the critical role of ventilator-associated infections in the transmission of MDR gram-negative bacteria in ICU settings. These findings further support concerns regarding inadequate infection control practices and prolonged invasive device utilization in tertiary healthcare facilities.

Prevalence of Multidrug-Resistant *Klebsiella pneumoniae*

Among the 210 collected specimens, 96 isolates were microbiologically confirmed as *Klebsiella pneumoniae*. Further antimicrobial susceptibility testing identified a considerable proportion of isolates as multidrug-resistant strains. The prevalence of MDR *Klebsiella pneumoniae* is presented in Table 4.

Table 4. Prevalence of MDR *Klebsiella pneumoniae* Isolates

Bacterial Classification	Frequency (n)	Percentage (%)
Non-MDR <i>Klebsiella pneumoniae</i>	28	29.2
MDR <i>Klebsiella pneumoniae</i>	68	70.8
Total Isolates	96	100

Source: Antimicrobial susceptibility testing results processed by the researchers, 2026

The results demonstrate that 70.8% of *Klebsiella pneumoniae* isolates were categorized as multidrug-resistant. This prevalence indicates a critically high level of antimicrobial resistance within ICU environments in Pakistan. Only 29.2% of isolates remained susceptible to multiple antibiotic classes. The high proportion of MDR isolates reflects excessive antibiotic exposure and potential transmission of resistant strains within healthcare facilities. Furthermore, the findings suggest that ICU patients are increasingly vulnerable to infections that are difficult to treat using conventional antimicrobial therapies.

The prevalence identified in this study aligns with global concerns regarding the rapid dissemination of resistant gram-negative pathogens in critical care settings. The findings also revealed that MDR isolates were predominantly detected in tracheal aspirates and blood cultures, indicating that respiratory and bloodstream infections represented the primary clinical manifestations associated with resistant *Klebsiella pneumoniae*. These infections are clinically significant because they are associated with higher mortality rates and prolonged hospitalization among critically ill patients.

Antibiotic Resistance Profiles

Antimicrobial susceptibility testing was conducted to determine resistance patterns of *Klebsiella pneumoniae* isolates against commonly prescribed antibiotics in ICU settings. The resistance profiles are summarized in Table 5.

Table 5. Antibiotic Resistance Profiles of *Klebsiella pneumoniae* Isolates

Antibiotic Category	Resistance Rate (%)
Third-Generation Cephalosporins	82.3
Fluoroquinolones	76.5
Aminoglycosides	63.2
Carbapenems	58.8
Beta-Lactam Combination Agents	54.4

Source: CLSI-based antimicrobial susceptibility testing data, 2026

Table 5 shows that the highest resistance rates were observed against third-generation cephalosporins, reaching 82.3%. This finding indicates extensive resistance to antibiotics commonly used as first-line empirical therapies for gram-negative infections. Resistance to fluoroquinolones was also remarkably high, suggesting widespread overuse of these agents in hospital settings.

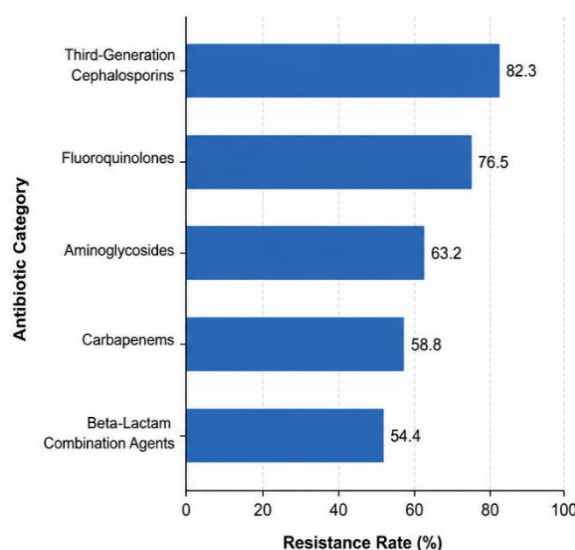


Figure 2. Antibiotic Resistance Rates Among MDR *Klebsiella pneumoniae* Isolates in ICU Patients

Source: Antimicrobial susceptibility testing results, 2026

Carbapenem resistance reached 58.8%, representing a particularly alarming finding because carbapenems are frequently considered last-resort antibiotics for severe MDR bacterial infections. The emergence of carbapenem-resistant *Klebsiella pneumoniae* substantially limits therapeutic options and increases the likelihood of treatment failure. The resistance profile identified in this study demonstrates the progressive decline in antibiotic effectiveness within ICU settings. Furthermore, multidrug resistance across multiple antibiotic categories indicates possible dissemination of ESBL-producing and carbapenemase-producing strains among hospitalized patients. The findings additionally revealed that isolates obtained from patients with prolonged ICU stays exhibited significantly higher resistance rates compared to those from patients with shorter hospitalization durations. This observation suggests that prolonged exposure to hospital environments and repeated antibiotic administration contribute to the development and transmission of resistant bacterial strains.

Association Between Clinical Variables and MDR Occurrence

Statistical analysis was performed to evaluate the association between selected clinical variables and the occurrence of MDR *Klebsiella pneumoniae*. The results are presented in Table 6.

Table 6. Association Between Clinical Factors and MDR Occurrence

Clinical Variable	MDR Cases (%)	p-value
ICU Stay >10 Days	78.4	0.002
Mechanical Ventilation	81.1	0.001
Prior Antibiotic Exposure	74.6	0.004
Urinary Catheter Use	68.2	0.021

Source: Statistical analysis using SPSS version 26, 2026

The analysis demonstrated statistically significant associations between several clinical variables and the occurrence of MDR *Klebsiella pneumoniae*. Patients who remained in ICU wards for more than 10 days exhibited significantly higher MDR infection rates compared to patients with shorter hospitalization periods. Similarly, mechanical ventilation was strongly associated with MDR occurrence, highlighting the role of ventilator-associated infections in the spread of resistant pathogens.

Prior exposure to broad-spectrum antibiotics also demonstrated a significant relationship with MDR detection. This finding supports the hypothesis that excessive empirical antibiotic utilization contributes to selective microbial pressure and resistance development. Additionally, urinary catheter use was significantly associated with MDR infections, indicating that invasive medical devices remain important risk factors for healthcare-associated bacterial transmission. These findings collectively suggest that ICU-related clinical interventions and prolonged hospitalization substantially increase vulnerability to MDR *Klebsiella pneumoniae* infections. The results further emphasize the urgent need for stricter infection prevention strategies, rational antibiotic prescribing practices, and enhanced antimicrobial stewardship programs in Pakistani healthcare institutions.

Multidrug-Resistant *Klebsiella pneumoniae* and the Escalating Challenge of ICU-Associated Antimicrobial Resistance in Pakistan

The findings of this study demonstrate a critically high prevalence of multidrug-resistant (MDR) *Klebsiella pneumoniae* among Intensive Care Unit (ICU) patients in Pakistan, indicating that antimicrobial resistance has become a substantial threat within tertiary healthcare institutions. The predominance of MDR isolates identified in respiratory and bloodstream specimens reflects the growing vulnerability of critically ill patients to healthcare-associated infections caused by resistant gram-negative bacteria (Halat & Moubareck, 2024; Shadvar et al., 2026). These findings reinforce the global concern that ICU environments represent one of the primary reservoirs for the emergence and dissemination of antimicrobial-resistant pathogens due to intensive antibiotic exposure, invasive clinical procedures, and prolonged hospitalization.

The high proportion of MDR *Klebsiella pneumoniae* isolates identified in this study is consistent with previous international investigations conducted in Asian and Middle Eastern healthcare settings. Earlier studies in China, India, and Saudi Arabia similarly reported increasing prevalence of MDR and carbapenem-resistant *Klebsiella pneumoniae* among ICU patients, particularly in tertiary referral hospitals characterized by high antibiotic consumption and overcrowded clinical environments. The similarity between these findings and the present study suggests that developing healthcare systems experience comparable structural and clinical challenges in controlling resistant bacterial transmission. However, the prevalence observed in this research appears relatively higher than reports from some European healthcare systems where stricter antimicrobial stewardship policies and infection prevention protocols have been systematically implemented. This difference indicates that variations in healthcare governance, antibiotic regulation, and hospital

surveillance systems substantially influence resistance prevalence across countries (Pandey et al., 2022; Patel et al., 2023; Coque et al., 2023).

One of the most significant findings of this study concerns the elevated resistance rates against third-generation cephalosporins and fluoroquinolones. These antibiotics are widely prescribed in ICU settings as empirical therapies for severe bacterial infections (Ippolito & Cortegiani, 2023; Timsit et al., 2025; Garduno & Martin-Loeches, 2022). The extensive resistance identified in this research indicates that conventional empirical treatment strategies may no longer provide adequate therapeutic effectiveness against ICU-associated *Klebsiella pneumoniae* infections in Pakistan. Previous studies have similarly demonstrated that excessive and inappropriate utilization of broad-spectrum antibiotics accelerates selective microbial pressure, thereby promoting the emergence of resistant bacterial strains. The current findings therefore support existing antimicrobial resistance theories emphasizing the relationship between irrational antibiotic exposure and multidrug resistance development.

The detection of substantial carbapenem resistance among *Klebsiella pneumoniae* isolates is particularly alarming because carbapenems are commonly regarded as last-resort antibiotics for severe gram-negative infections. Several international studies have linked carbapenem resistance to the dissemination of carbapenemase-producing genes such as *bla*NDM, *bla*KPC, and *bla*OXA-48, which contribute to resistance against multiple antimicrobial agents simultaneously. The emergence of carbapenem-resistant *Klebsiella pneumoniae* in Pakistani ICUs therefore suggests the possible circulation of highly resistant genetic determinants within hospital environments (Rizvi et al., 2025; Gondal et al., 2023; Zada et al., 2025). Compared with previous Pakistani studies that primarily focused on general resistance surveillance, this research provides more context-specific evidence regarding the severity of carbapenem resistance in ICU-associated infections. The novelty of this study lies in its focused analysis of MDR *Klebsiella pneumoniae* detection within critical care settings following the post-pandemic increase in antibiotic utilization, which has intensified antimicrobial resistance globally.

Another important finding relates to the association between prolonged ICU hospitalization and MDR occurrence. Patients who remained in ICU wards for extended periods exhibited significantly higher risks of MDR infection compared to those with shorter hospital stays. This finding aligns with previous epidemiological studies demonstrating that prolonged hospitalization increases exposure to contaminated healthcare environments, invasive medical devices, and repeated antibiotic administration. Critically ill patients often experience compromised immune function, further increasing susceptibility to opportunistic bacterial colonization. In this context, ICU wards function not only as treatment centers but also as environments where resistant pathogens can circulate rapidly between patients, healthcare workers, and clinical equipment.

Mechanical ventilation also emerged as a significant risk factor associated with MDR *Klebsiella pneumoniae* infection. The predominance of resistant isolates in tracheal aspirates strongly indicates the importance of ventilator-associated respiratory infections in ICU transmission dynamics (Berhe et al., 2025). Previous international studies similarly identified ventilator-associated pneumonia as one of the most common manifestations of MDR gram-negative bacterial infection among critically ill patients. The consistency between these findings and earlier research reinforces the argument that invasive respiratory support procedures contribute substantially to bacterial colonization and cross-transmission in intensive care settings. Inadequate sterilization practices, prolonged ventilator use, and insufficient infection control monitoring may further exacerbate this problem in resource-limited healthcare systems.

The association between prior antibiotic exposure and the detection of MDR found in this study is also consistent with the current antimicrobial stewardship literature. Prescribing antibiotics without microbiological confirmation is still very prevalent in many developing healthcare systems, including Pakistan, and for a wide range of conditions. This practice is important because it creates selective pressure to the survival of resistant bacteria and helps to reduce susceptible bacteria. Earlier studies have already highlighted the importance of inappropriate antibiotic prescribing behaviours by health care professionals and their link to escalating antibiotic resistance trends. Based on the results of this study, there is a great need to enhance the antibiotic stewardship programs in Pakistani hospitals and especially in the ICU setting where antibiotic use is very high.

This study is among the many studies currently available, which are studying the epidemiology of antimicrobial resistance in developing countries. The methods used to address antimicrobial resistance today tend to concentrate on the interactions between adaptation of micro-organisms, the absence of health care facilities and the inappropriate use of antibiotics. The present results validate such theoretical notions by showing how clinical activities in ICU and the length of hospital stays promote resistance dissemination. Moreover, this study contributes to the existing literature by presenting new empirical evidence from a context which is underrepresented in the global antimicrobial resistance literature—namely, Pakistan, which has significant antimicrobial resistance burdens.

This study is also of much practical significance. As MDR prevalence has been observed and alarming resistance to carbapenems, it serves as a critical piece of evidence to support health policy makers, hospital administrators and hospital infection control teams in Pakistan (Maryam et al., 2025; Umair et al., 2024). The results suggest that the level of infection prevention and antibiotic prescription practices today might be inadequate for controlling the spread of resistant bacterial infections in the ICU setting. Thus, hospitals will be increasing their microbiological surveillance systems, compliance to hand hygiene, better sterilization measures, and encourage evidence-based antibiotic use. Empirical antibiotic use should also be avoided by incorporating the standard antibiotic surveillance into the care provided in the ICU.

This study has implications beyond the hospital setting for infection management. This problem of anti-microbial resistance is not only a clinical problem but also a public health and an economic problem. People with resistant infections are more likely to have a longer hospital stay, higher death rate and require intensive care, which increases health-care costs. These impacts in low and middle income countries like Pakistan, are adding to scarce health care resources. Thus, the results of this study help substantiate the need for more comprehensive national antimicrobial resistance policies, such as more stringent regulations on antibiotics, public education campaigns on the misuse of antibiotics and investment in laboratory diagnostic capacity.

This study has a number of limitations that should be noted, however. The research was carried out in selected tertiary hospitals, which might not be generalizable to smaller healthcare facilities or rural healthcare facilities in Pakistan. Second, the study was based on phenotypic antimicrobial susceptibility testing and molecular genetic analysis to identify specific antimicrobial resistance genes was not used extensively. Therefore, it was impossible to fully understand the exact genetic mechanisms behind carbapenem and multidrug resistance. Finally, the cross sectional design does not allow for the assessment of within-person changes in resistance over time and causal relationships between clinical risk factors and MDR. The restrictions emphasize the complexity of the issue of antimicrobial resistance and the need to research it in a broadened and extended perspective.

Future studies should therefore be multicenter, longitudinal and include a larger number of patients with different geographical regions of Pakistan. Molecular identification of resistance genes such as blaNDM, blaKPC and blaOXA-48 will provide further information on the transmission of resistance and provide the genetic epidemiology. Moreover, the effectiveness of antimicrobial stewardship interventions, infection prevention strategies, and rapid diagnostic technologies on the transmission of MDR in the ICU should be assessed in future studies. Comparative studies aimed at public and private healthcare institutions may also provide an idea of structural differences that can influence the occurrence of antimicrobial resistance.

CONCLUSION

It is evident from this study that the multidrug-resistant (MDR) *Klebsiella pneumoniae* is a major healthcare-associated pathogen in the Intensive Care Units in Pakistan. Results showed high levels of resistance to key classes of antibiotics, such as cephalosporins and carbapenems, especially in patients who had been on mechanical ventilation, had stayed in the critical care unit for longer than seven days and had had previous antibiotic usage. The study also adds to the evolving body of knowledge around the epidemiology of antimicrobial resistance in developing healthcare systems and offers empirical data to support focused efforts of antimicrobial stewardship and infection control policy in tertiary hospitals.

The results indicate the critical need to develop better microbiological monitoring, rational antibiotic use, and enhanced infection prevention efforts in the ICU. However, the cross sectional design of this study and lack of molecular resistance analysis were limited. Future research should include multicenter longitudinal investigations and genetic characterization of resistance mechanisms to get wider picture of transmission dynamics of MDR KP in Pakistan.

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