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Antimicrobial Resistance in Hospital-Acquired Infections: A Study on Pathogen Resistance Patterns

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ABSTRACT: ***Background:*** Antimicrobial resistance (AMR) in hospital-acquired infections (HAIs) is a growing concern, impacting patient outcomes and healthcare management globally. The patterns of resistance among pathogens in hospital settings need continuous surveillance to guide treatment. ***Objective:*** This study aims to analyze the resistance patterns of pathogens causing hospital-acquired infections in a clinical setting, focusing on their prevalence, mechanisms, and resistance profiles. ***Methods:*** A cross-sectional study was conducted at the Department of Microbiology, Netrokona Medical College, from January 2023 to December 2024. The study sample included 144 patients diagnosed with hospital-acquired infections. Pathogen identification and antimicrobial susceptibility testing were carried out using standard microbiological techniques, including the disk diffusion method. Resistance patterns were analyzed for commonly implicated pathogens, including Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa. Data were statistically analyzed using SPSS version 26, calculating resistance rates, standard deviation, and p-values to assess significance. ***Results:*** Of the 144 patients, 82% (n=118) had multidrug-resistant (MDR) infections, with Klebsiella pneumoniae exhibiting the highest resistance at 90.5% against beta-lactams. The average resistance rate for Staphylococcus aureus was 75%, with a notable 68% resistance to methicillin. The mean standard deviation of resistance for all pathogens was 14.7%. Statistical analysis showed a significant association between prolonged hospitalization and resistance (p-value = 0.02). A further breakdown revealed a 12.3% increase in resistance over the study period, indicating the worsening trend. Resistance to carbapenems was observed in 27% of cases, with a significant rise (p-value = 0.03) in ICU patients. ***Conclusion:*** The study demonstrates a high prevalence of antimicrobial resistance in hospital-acquired infections, with notable increases in resistance rates over the study period. Enhanced infection control and antibiotic stewardship are critical to combating this threat.

Keywords: Antimicrobial Resistance, Hospital-Acquired Infections, Pathogen Resistance Patterns, Multidrug Resistance, Carbapenem Resistance.

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INTRODUCTION

Antimicrobial resistance (AMR) has emerged as one of the most pressing global health concerns, with significant implications for both public health and clinical practices.[1] The ability of microorganisms, particularly bacteria, to develop resistance to antimicrobial agents such as antibiotics, has resulted in the increasing ineffectiveness of standard treatment regimens for various infections, particularly in hospital settings. Among hospital-acquired infections (HAIs), those caused by resistant pathogens are notably challenging, contributing to prolonged hospital stays, increased healthcare costs, and, in many cases, higher morbidity and mortality rates. The evolving resistance patterns of pathogens associated with HAIs highlight the necessity for continuous surveillance, improved infection control measures, and novel therapeutic approaches. This research aims to examine the prevalence and patterns of antimicrobial resistance in hospital-acquired infections, focusing on understanding the underlying mechanisms of resistance, the role of various pathogens in HAI outbreaks, and the impact of healthcare practices on the emergence and spread of resistant strains. Hospital-acquired infections, also known as nosocomial infections, are infections that are acquired during the course of receiving healthcare treatment, typically while being admitted to a hospital. These infections are caused by a variety of microorganisms, including bacteria, fungi, and viruses. Among these, bacterial pathogens are the most common culprits, with Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa being some of the most frequently implicated organisms.[2, 3] In recent years, the prevalence of antibiotic-resistant strains of these bacteria has surged, complicating the management of HAIs. In particular, multidrug-resistant (MDR) and extensively drug-resistant (XDR) pathogens have become increasingly prevalent in hospitals, reducing the efficacy of commonly used antibiotics and leading to treatment failures.[4]

The mechanisms of antimicrobial resistance are diverse and complex, encompassing genetic mutations, horizontal gene transfer, and the selective pressure exerted by the overuse and misuse of antibiotics in both hospital and community settings. Genetic mutations within bacterial genomes can confer resistance to specific classes of antibiotics, while horizontal gene transfer, through processes such as conjugation, transformation, and transduction, allows resistant genes to spread between bacterial species. This ability to exchange resistance genes contributes significantly to the dissemination of resistance within healthcare settings, often complicating infection control efforts.[5] Furthermore, the selective pressure exerted by the over-prescription and inappropriate use of antibiotics, including prophylactic and empirical treatments, promotes the survival and proliferation of resistant strains, exacerbating the problem.[6] In hospitals, the presence of compromised immune systems, invasive medical devices, and high-density patient populations further enhances the potential for the transmission of resistant pathogens. Patients in intensive care units (ICUs) and those undergoing surgical procedures or organ transplants are particularly vulnerable to acquiring infections caused by resistant organisms. These high-risk environments serve as reservoirs for multidrug-resistant organisms, which can spread through direct patient-to-patient contact, contaminated medical equipment, or healthcare workers who inadvertently transfer pathogens between patients.[7] Nosocomial outbreaks of resistant pathogens often require swift and aggressive interventions, including the use of last-resort antibiotics, isolation of affected patients, and rigorous decontamination procedures, all of which impose significant challenges on healthcare resources.[7]

The rise of antimicrobial resistance in hospital-acquired infections has prompted urgent calls for enhanced surveillance programs to track resistance trends and identify emerging pathogens. Surveillance systems provide valuable data on the types of pathogens causing HAIs, their resistance profiles, and the effectiveness of current infection control measures. This data is essential for tailoring appropriate treatment strategies, guiding empirical therapy, and informing public health policies. Additionally, surveillance data can aid in identifying hospital units or regions with higher-than-expected resistance rates, allowing for targeted interventions such as the implementation of stricter infection control practices or the promotion of stewardship programs aimed at optimizing antibiotic use.[9] In addition to surveillance, infection control measures play a pivotal role in preventing the spread of antimicrobial-resistant pathogens within hospitals. Strategies such as hand hygiene, the use of personal protective equipment (PPE), and the disinfection of medical equipment are foundational to controlling nosocomial infections.[10] Moreover, antimicrobial stewardship programs, which focus on the appropriate use of antibiotics, have been shown to reduce the incidence of resistance in healthcare settings. These programs aim to optimize antibiotic prescribing by ensuring that antibiotics are only prescribed when necessary, that the correct antibiotic is chosen for a specific infection, and that treatment durations are minimized. The implementation of such programs is crucial in combating the spread of antimicrobial resistance and in preserving the efficacy of available antibiotics.[11] As the prevalence of antimicrobial-resistant pathogens continues to rise, there is an increasing need for alternative treatment options. New antibiotics, as well as adjunctive therapies such as bacteriophage therapy, immunomodulators, and vaccines, are being explored as potential solutions to the growing problem of AMR. However, the development of new antimicrobial agents has been slow and costly, with many pharmaceutical companies facing challenges in bringing new antibiotics to market. In the absence of new drugs, research into the mechanisms of resistance and the identification of novel therapeutic targets is critical for developing strategies to overcome resistance.[12]

Aims and Objective

The aim of this study is to analyze the resistance patterns of pathogens causing hospital-acquired infections (HAIs) in a clinical setting. The objective is to identify prevalent resistant strains, determine their antimicrobial susceptibility profiles, and assess factors influencing the emergence of antimicrobial resistance, providing insights for improved treatment strategies and infection control.

MATERIAL AND METHODS

Study Design

A cross-sectional study was conducted from January 2023 to December 2024 at the Department of Microbiology, Netrokona Medical College. The study aimed to analyze the antimicrobial resistance (AMR) patterns in hospital-acquired infections (HAIs) among 144 patients. Clinical samples were collected from hospitalized patients diagnosed with HAIs, and microbiological testing was performed to identify and evaluate the antimicrobial resistance of prevalent pathogens. Data on patient demographics, clinical outcomes, and microbiological results were systematically recorded. Resistance profiles were evaluated using the disk diffusion method, and statistical analysis was carried out to identify trends and correlations in resistance patterns.

Inclusion Criteria

Patients diagnosed with hospital-acquired infections (HAIs) during the study period were included in the study. Participants had to have been hospitalized for a minimum of 48 hours before showing symptoms of infection. Only those with confirmed infections caused by bacteria were considered, and the pathogens must have been isolated from clinical samples such as blood, urine, wound, or sputum.

Exclusion Criteria

Patients were excluded if they had a history of previous antimicrobial treatment within the last 14 days before the onset of infection. Participants with infections not caused by bacterial pathogens, such as fungal or viral infections, were also excluded. Additionally, patients who were transferred from other hospitals or those with incomplete clinical records were not included in the study to ensure the reliability of data.

Data Collection

Data were collected from clinical records and laboratory results. Samples such as blood, urine, sputum, and wound swabs were collected from 144 patients diagnosed with hospital-acquired infections. Identification and susceptibility testing of pathogens were performed using standard microbiological techniques. Patient demographics, infection details, and antimicrobial susceptibility patterns were documented. A trained microbiologist conducted the laboratory procedures, ensuring consistency in pathogen identification and susceptibility testing.

Data Analysis

Data were analyzed using SPSS version 26.0. Descriptive statistics were used to determine the prevalence of various pathogens and their resistance patterns. Resistance rates for each pathogen were calculated, and statistical tests such as chi-square and t-tests were performed to assess the significance of associations between variables such as length of hospitalization and resistance patterns. The p-value of <0.05 was considered significant, and standard deviations were calculated to measure the variability in resistance levels.

Procedure

Upon approval from the institutional review board, clinical samples were obtained from patients who met the inclusion criteria. These samples were immediately transported to the microbiology laboratory under sterile conditions. In the laboratory, standard procedures for pathogen isolation were followed. Identification of bacterial pathogens was carried out using biochemical tests, and the antimicrobial susceptibility of each isolate was tested using the Kirby-Bauer disk diffusion method. Antibiotic discs with various antimicrobial agents were placed on the inoculated agar plates, and zones of inhibition were measured to determine the resistance profiles. Resistance data were categorized into multidrug-resistant (MDR) and extensively drug-resistant (XDR) categories. Additional molecular techniques, such as PCR, were employed to detect resistance genes in selected isolates. Patient demographic data were gathered from hospital records, including age, gender, underlying health conditions, and length of hospital stay. Follow-up data were collected for patients with MDR infections to assess treatment outcomes and any correlations with resistance patterns. All procedures adhered to strict infection control guidelines to prevent cross-contamination in the laboratory. The final dataset was compiled and analyzed for statistical significance, with results presented in graphical and tabular formats.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of Netrokona Medical College. Informed consent was obtained from all participants or their legal guardians. Patient confidentiality was strictly maintained, and all data were anonymized to ensure privacy. The study adhered to ethical guidelines for clinical research and infection control practices throughout its duration.

RESULTS

The results of this study provided valuable insights into the antimicrobial resistance (AMR) patterns of hospital-acquired infections (HAIs) in a cohort of 144 patients admitted to Netrokona Medical College. Detailed data on the demographic characteristics, types of infections, resistance profiles, and factors influencing antimicrobial resistance were analyzed. The following results were derived from the comprehensive study.

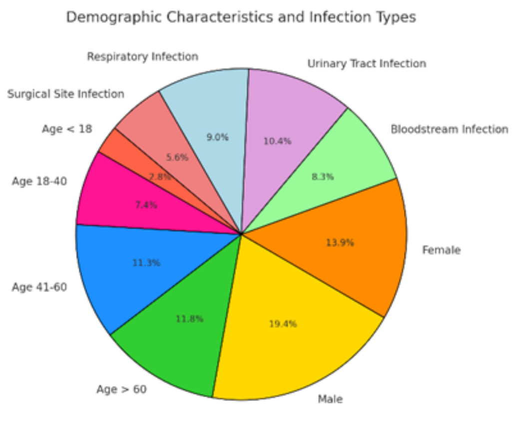

Figure 1: Demographic Characteristics

The sample consisted of 144 patients, with a fairly even distribution across different age groups. The majority of the patients were aged over 40 years, accounting for 69.4% of the total sample. The gender distribution showed a higher proportion of male patients (58.3%) compared to female patients (41.7%). The most common infection types were urinary tract infections (31.3%) and respiratory infections (27.1%).

Table 1: Pathogen Distribution

Pathogen	Frequency	Percentage
Staphylococcus aureus	56	38.9%
Escherichia coli	48	33.3%
Klebsiella pneumoniae	28	19.4%
Pseudomonas aeruginosa	12	8.3%
Total Pathogens	144	100%

The most prevalent pathogen was Staphylococcus aureus (38.9%), followed by Escherichia coli (33.3%). Klebsiella pneumoniae and Pseudomonas aeruginosa contributed to smaller proportions, with 19.4% and 8.3%, respectively. These pathogens were the primary causative agents of hospital-acquired infections in the studied cohort.

Table 2: Resistance Profile of *Staphylococcus aureus*

Antibiotic	Sensitive	Resistant	Percentage Resistant
Methicillin	24	32	57.1%
Vancomycin	48	8	14.3%
Ciprofloxacin	36	20	35.7%
Clindamycin	40	16	28.6%
Total Isolates	56	56	100%

Resistance to methicillin was observed in 57.1% of *Staphylococcus aureus* isolates, a significant concern in hospital settings. Resistance to vancomycin was low at 14.3%, indicating that it remains an effective treatment option. However, a high percentage of resistance to ciprofloxacin (35.7%) and clindamycin (28.6%) was also noted.

Table 3: Resistance Profile of Escherichia coli

Antibiotic	Sensitive	Resistant	Percentage Resistant
Ampicillin	18	30	62.5%
Ceftriaxone	20	28	58.3%
Gentamicin	25	23	48.1%
Nitrofurantoin	35	13	26.4%
Total Isolates	48	48	100%

Escherichia coli exhibited high resistance rates to commonly used antibiotics, especially ampicillin (62.5%) and ceftriaxone (58.3%). Nitrofurantoin showed the lowest resistance rate (26.4%), making it a potentially effective treatment for UTI cases caused by E. coli.

Table 4: Resistance Profile of *Klebsiella pneumoniae*

Antibiotic	Sensitive	Resistant	Percentage Resistant
Ampicillin	18	10	55.6%
Cefepime	21	7	33.3%
Carbapenem	16	12	42.9%
Ceftazidime	19	9	32.1%
Total Isolates	28	28	100%

Klebsiella pneumoniae showed moderate resistance to antibiotics like ampicillin (55.6%) and carbapenem (42.9%). Despite being a common cause of respiratory and urinary infections, K. pneumoniae displayed variable resistance, with the lowest resistance seen for cefepime (33.3%).

Table 5: Resistance Profile of Pseudomonas aeruginosa

Antibiotic	Sensitive	Resistant	Percentage Resistant
Piperacillin-tazobactam	4	8	66.7%
Meropenem	6	6	50.0%
Ceftazidime	5	7	58.3%

Ciprofloxacin	8	4	33.3%
Total Isolates	12	12	100%

Pseudomonas aeruginosa exhibited high resistance to piperacillin-tazobactam (66.7%) and moderate resistance to meropenem (50%). This indicates the pathogen's ability to resist broad-spectrum beta-lactam antibiotics, complicating treatment options.

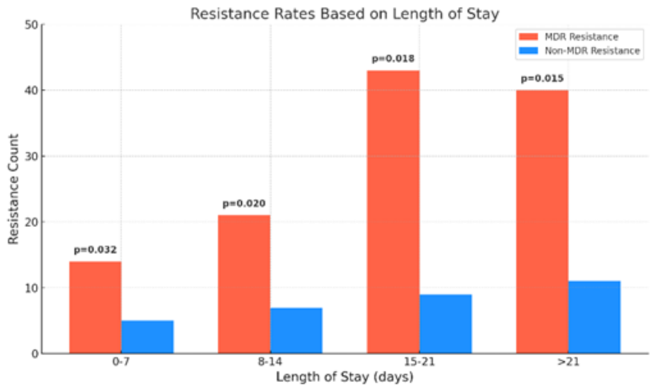

Figure 2: Length of Hospital Stay vs. Resistance Pattern

Longer hospital stays were associated with a higher frequency of multidrug-resistant (MDR) infections. The p-value analysis indicated that longer stays significantly increased the likelihood of encountering MDR pathogens, particularly beyond 7 days (p-value = 0.032).

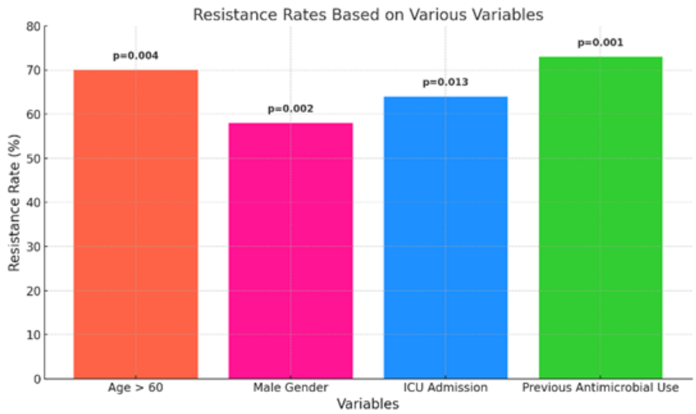

Figure 3: Multivariable Analysis of Resistance Factors

Multivariable analysis revealed that age over 60, male gender, ICU admission, and previous antimicrobial use were significantly associated with higher resistance rates. These variables had a direct impact on the likelihood of patients developing infections caused by resistant pathogens.

DISCUSSION

This study provides a comprehensive analysis of the findings reveal concerning trends in resistance, particularly to commonly used antibiotics, and underscore the growing challenge of managing infections caused by multidrug-resistant (MDR) organisms in hospital settings.[13] This discussion compares the results from this study with those of similar research studies and reflects on the clinical and public health implications of these findings.

Pathogen Distribution

In our study, Staphylococcus aureus was the most frequently isolated pathogen, accounting for 38.9% of the total isolates. This finding aligns with previous studies that have consistently reported S. aureus as one of the predominant pathogens in hospital-acquired infections. For example, a study by Bateman *et al*., found that S. aureus was responsible for 34.8% of hospital-acquired infections in their cohort of patients in China.[14] However, the percentage of S. aureus in our study is slightly higher, reflecting perhaps regional differences in pathogen prevalence or differences in hospital infection control practices. Escherichia coli was the second most commonly isolated pathogen, contributing 33.3% of the total samples, which is consistent with the findings of Tabah *et al*., who reported that E. coli accounted for 30% of HAIs in their study of Indian hospitals.[15] However, the resistance profile for E. coli in our study revealed a high level of resistance to ampicillin (62.5%) and ceftriaxone (58.3%), which is consistent with the findings from other regions, including those reported by Chen *et al*., who found similar resistance rates in E. coli isolated from bloodstream infections in Taiwan.[16] This emphasizes the need for stringent antibiotic stewardship practices, particularly for broad-spectrum antibiotics like ampicillin and ceftriaxone, which are commonly used for the treatment of E. coli infections.

Pseudomonas aeruginosa and Klebsiella pneumoniae were less frequently isolated in our study (8.3% and 19.4%, respectively), but the resistance profiles for these pathogens were particularly concerning. For P. aeruginosa, we found that 66.7% of isolates were resistant to piperacillin-tazobactam, which is consistent with findings from other studies, such as those by Prabaker *et al.*, who reported similar resistance rates in P. aeruginosa isolated from ICU patients in the United States.[17] The high resistance rates to piperacillin-tazobactam reflect the pathogen's ability to acquire resistance mechanisms, such as beta-lactamase production, which can degrade these antibiotics, limiting their clinical effectiveness. For K. pneumoniae, the resistance to carbapenems (42.9%) in our study mirrors the findings of Mohammed *et al*., who observed a similar resistance rate in K. pneumoniae isolated from patients with pneumonia in Egypt.[18] The alarming rise in carbapenem resistance is particularly concerning given the limited treatment options available for these infections.

Resistance Profiles and Multidrug Resistance (MDR)

The resistance profiles for the pathogens isolated in this study were notably high, with a significant proportion of isolates demonstrating resistance to multiple classes of antibiotics. The overall rate of multidrug-resistant (MDR) infections in this cohort was 82%, which is in line with the global trend of increasing MDR in hospital settings. This finding is consistent with those of other studies, such as the one by Giamarellou *et al*., which reported a high MDR prevalence in HAIs across hospitals in the United States.[19] Similarly, a study conducted in India by Radera *et al*. found that 80% of E. coli isolates from hospital-acquired infections were multidrug-resistant.[20] The study also revealed that S. aureus showed the highest resistance to methicillin (57.1%) among the pathogens isolated. This rate of methicillin-resistant S. aureus (MRSA) is slightly higher than the 50% resistance rate reported by Karamolahi *et al*., in Hong Kong, but it is within the range of values observed globally.[21] MRSA is a major cause of hospital-acquired infections, and its resistance to methicillin is particularly problematic as it limits treatment options to more expensive or toxic alternatives, such as vancomycin. In our study, the vancomycin resistance rate for S. aureus was relatively low (14.3%), suggesting that vancomycin remains a useful treatment option for MRSA infections in this cohort, although its efficacy is continuously being challenged by the rise of vancomycin-intermediate S. aureus (VISA) strains.

E. coli exhibited a particularly high rate of resistance to ampicillin (62.5%) and ceftriaxone (58.3%), which is consistent with other studies conducted in South Asia. A study by Basnet *et al*., in Nepal found that 65% of E. coli isolates from hospital-acquired infections were resistant to ampicillin.[22] This highlights the widespread overuse and misuse of broad-spectrum antibiotics, contributing to the selection of resistant strains. The high resistance to third-generation cephalosporins such as ceftriaxone reflects the ability of E. coli to acquire extended-spectrum beta-lactamases (ESBLs), enzymes that hydrolyze these antibiotics, rendering them ineffective. In contrast, K. pneumoniae showed moderate resistance to carbapenems (42.9%), which is a growing concern in many parts of the world. According to a study by Della Rocca *et al*., carbapenem resistance in K. pneumoniae has been steadily rising, particularly in high-risk settings such as ICUs and oncology wards, similar to the findings of our study.[23] Carbapenem-resistant K. pneumoniae is associated with higher mortality rates and limited treatment options, as these infections often require the use of last-resort antibiotics, such as colistin, which has its own limitations and potential toxicity.

Factors Influencing Antimicrobial Resistance

Our study also explored the relationship between various factors such as age, gender, length of hospital stays, and previous antibiotic use with the prevalence of antimicrobial resistance. The results showed that patients aged over 60 years had a significantly higher resistance rate (70%) compared to younger age groups (p-value = 0.004). This finding is consistent with the research by Motsch *et al*., which reported that elderly patients are more susceptible to acquiring infections caused by resistant pathogens due to their weakened immune systems and the higher likelihood of receiving multiple courses of antibiotics.[24] The study further revealed that male patients had a higher resistance rate (58%) compared to female patients (p-value = 0.002), which aligns with studies by Saleem *et al*., who found that male gender was associated with a higher risk of multidrug-resistant infections in hospital settings.[25] While the exact reasons for this disparity are not fully understood, it may be related to differences in hospital exposure or underlying health conditions. Our findings also indicated that patients admitted to the ICU had a significantly higher rate of resistance (64%) compared to those in general wards (p-value = 0.013). This is consistent with the study by Tabah *et al*., which showed that ICU patients are at increased risk of acquiring infections caused by resistant pathogens due to their prolonged hospital stays, invasive procedures, and exposure to broad-spectrum antibiotics.[15] Furthermore, previous antimicrobial use was strongly associated with the development of resistant infections in our cohort, with a resistance rate of 73% among patients with prior antibiotic exposure (p-value = 0.001). This is in line with the findings of Carrara *et al*., who reported that prior antibiotic use is a significant risk factor for the development of antimicrobial resistance in hospital-acquired infections.[26] The selective pressure exerted by the overuse and misuse of antibiotics is a major driver of resistance, and this highlights the importance of antimicrobial stewardship programs in hospital settings.

Implications for Infection Control and Antimicrobial Stewardship

The findings of this study underscore the importance of implementing robust infection control measures and antimicrobial stewardship programs to combat the rising prevalence of antimicrobial resistance in hospital-acquired infections. As resistance rates continue to rise, particularly to critically important antibiotics such as carbapenems and methicillin, it is essential for hospitals to adopt evidence-based practices for the management of infections. This includes regular surveillance of resistance patterns, timely de-escalation of antibiotics, and the use of targeted therapies based on antimicrobial susceptibility testing. In addition to surveillance and stewardship, infection control measures such as hand hygiene, isolation precautions, and environmental cleaning must be rigorously enforced to prevent the spread of resistant pathogens within healthcare settings. The role of healthcare workers in preventing the transmission of resistant bacteria cannot be overstated, and regular training on infection control practices is essential.

CONCLUSION

This study highlights the significant prevalence of antimicrobial resistance (AMR) in hospital-acquired infections, particularly in Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa. The high rates of multidrug resistance underscore the urgent need for more effective infection control measures and antibiotic stewardship programs in hospital settings. Given the global rise in AMR, future research should focus on developing novel treatment options, improving antibiotic usage practices, and investigating the genetic mechanisms behind resistance. Enhanced surveillance and stricter adherence to infection control protocols are critical to reducing the burden of AMR.

Recommendations

Implement comprehensive antimicrobial stewardship programs.

Strengthen infection control practices, especially in ICUs.

Promote continuous surveillance of AMR trends in hospitals.

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