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Original Research Article

Prevalence and Risk Factors of Carbapenem-Resistant Enterobacterales in Hospitalized Patients

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Abstract

Background: Antimicrobial resistance is a global public health problem, and Carbapenem-Resistant Enterobacterales (CRE) are one of the most important threats because of the lack of therapeutic alternatives and higher morbidity and mortality rates. Prevalence and risk factors for CREs are key areas observed to inform infection prevention and antimicrobial stewardship measures.

Methods: A cross-sectional observational study was carried out in a hospital setting from January to June 2025 among 100 hospitalized patients with culture-confirmed Enterobacterales infection. The processing of clinical specimens (urine, blood, pus, sputum, endotracheal aspirates, and wound swabs) was done by standard microbiological techniques. Antimicrobial susceptibility testing was performed by the Kirby–Bauer disk diffusion method according to Clinical and Laboratory Standards Institute (CLSI) guidelines. Data were analysed using SPSS, and a p-value of < 0.05 was considered statistically significant.

Results: The prevalence 32% of samples were found to be positive for CRE. The most common isolates were Escherichia coli (45%) and Klebsiella pneumoniae (32%). Significant independent risk factors identified were ICU admission, previous exposure to carbapenems, prolonged hospital stay, mechanical ventilation, urinary catheterization, and diabetes mellitus ($p<0.05$).

Conclusion: CRE was found to be prevalent among hospitalized patients, and this situation reinforces the need for ongoing surveillance, early detection in the laboratory, effective infection prevention and control measures and antimicrobial stewardship programs, all to prevent the spread of resistant pathogens and enhance clinical outcomes.

Keywords: Carbapenem-Resistant Enterobacterales, Antimicrobial Resistance, Hospitalized Patients, Risk Factors, Tertiary Care Hospital.

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Introduction

Antimicrobial resistance (AMR) has become one of the major threats to public health and threatening to set back efforts to prevent and treat infectious diseases and improve health [1]. The global spread of resistant microorganisms, caused partially by the use of antimicrobials in human medicine, veterinary medicine and agriculture that is not appropriate, has been promoted.

The World Health Organization (WHO) has declared CRE as one of the most critical bacterial pathogens that demand immediate research and development of new treatment strategies. Enterobacterales Escherichia coli, Klebsiella pneumoniae, Enterobacter spp. and Proteus spp., are known to cause infections in the context of hospital-acquired infections and community-acquired infections, including urinary tract infections, surgical site infections, intra-abdominal infections and pneumonia [2,3]. Imipenem, meropenem and ertapenem are considered to be last-resort antibiotics for the treatment of severe infections with multidrug-resistant Gram-negative microorganisms [4]. The growing resistance of carbapenems, largely via carbapenems enzyme production and other resistance mechanisms, has substantially reduced the effectiveness of these critical antibiotics and created major therapeutic challenges [5].

The incidence of CRE in India has increased significantly in the past decade, due to its high demand for antibiotic usage, the availability of poor-quality health facilities, poor infection control measures, and extended hospital stays [6,7]. Multidrug-resistant organisms have emerged as an important source of infection in tertiary care hospitals, especially the Intensive Care Unit (ICU), where patients who are already sick are likely to be exposed to invasive devices, mechanical ventilation, long hospital stays and often long courses of antibiotics [8,9].

These factors facilitate the transmission of resistant pathogens and increase the risk of healthcare-associated infections. To solve this growing problem, the Government of India has undertaken a significant initiative with the National Action Plan on Antimicrobial Resistance (NAP-AMR) and gives special attention to antimicrobial stewardship, infection prevention and control, surveillance and responsible use of antibiotics in health care facilities [10].

The clinical consequences of CRE infections are significant, as they are associated to higher rates of morbidity, mortality, and longer hospital stays, as well as treatment restrictions and high cost of healthcare [11]. The financial and logistical strain on healthcare systems, especially in low-resource areas, is significant, as patients with CRE typically need long courses of costly reserve antibiotics, intensive supportive therapy and prolonged hospital stays [12]. The targeted infection control measures and to deploy antimicrobial stewardship interventions, it is therefore crucial to identify risk factors for acquisition of CRE early [13].

However, epidemiological information from Eastern India, especially the State of Bihar, remains limited in spite of the rising burden of CRE in India. Most published studies are from tertiary care centres in other regions and there is limited knowledge about the local burden and risk factors associated with CRE in this geographically and demographically unique population. To inform empirical antibiotic treatment, fortify infection control measures, and contribute to regional antimicrobial resistance monitoring, it is crucial to generate institution-specific evidence from PMCH, Bihar's important tertiary care referral hospital. In the present study, the investigators were required to find the prevalence of carbapenem-resistant Enterobacterales among the hospitalized patients and the associated clinical risk factors in a tertiary care hospital in Bihar.

Objectives

- To determine the prevalence of CRE among hospitalized patients.
- To identify demographic and clinical risk factors associated with CRE infection.

Materials and Methods

Study Design and Setting: The present study was a cross-sectional, observational study done in the Department of Microbiology, PMCH, Patna, Bihar, India. PMCH is a tertiary care teaching hospital that admits a huge number of patients from Bihar and adjacent states. This study aimed to assess the prevalence of CRE in hospitalized patients and to explore the clinical risk factors associated with CRE infection between January and June 2025 for 6 months.

Study Population and Sample Size: A total of 100 consecutive hospitalized patients with clinically suspected bacterial infections who had positive culture results were recruited using a consecutive sampling technique. Only one isolate of each patient was used to prevent duplication of isolates and to accurately estimate the prevalence.

Inclusion Criteria

- Patients 18 years of age or older.
- Patients who are admitted as inpatients to any department except outpatient departments.
- Patients clinically suspected of bacterial infection.
- Patients with positive culture reports where Enterobacterales organisms are cultured.

Exclusion Criteria

- Outpatients attending the hospital.
- Separate strains of a bacterium from the same patient.
- Clinical specimens that are contaminated or not properly collected.
- Patients who declined to provide written informed consent.

Specimen Collection and Laboratory Procedures: Specimens from patients were aseptically collected from clinical materials including urine, blood, pus and sputum, endotracheal aspirates and wound swabs following standard microbiological protocols. Bacterial isolates were obtained by culturing the samples on suitable media and identified by using conventional biochemical tests.

Somewhere available, automated identification systems were used for increased diagnostic accuracy.

Antimicrobial Susceptibility Testing: The antimicrobial susceptibility testing was done by the Kirby–Bauer disk diffusion method on Mueller–Hinton agar, following the guidelines of the CLSI. Antibiotic discs of imipenem, meropenem and ertapenem were used to test carbapenem susceptibility. Isolates with reduced susceptibility

were further tested by the Modified Carbapenem Inactivation Method (mCIM) and EDTA-modified Carbapenem Inactivation Method (eCIM) (where applicable) to corroborate carbapenems production.

Data Collection: Demographic data (age, sex) and clinical data (such as admission to the ICU, hospital stay, diabetes mellitus, hypertension, chronic kidney disease, previous hospitalization, prior antibiotic use, mechanical ventilation, urinary catheter, central venous catheter, recent surgery, and immunosuppression) were collected on a structured data collection form. The presence or absence of CRE infection was the main outcome variable.

Statistical Analysis:

The data were analysed with SPSS version. Data for continuous variables were presented as means ± SDs, and data for categorical variables were presented as frequencies and percentages. The Chi-square test or Fisher's exact test was used to assess the association between variables. Multivariable logistic regression analysis was used to determine independent risk factors and odds ratios (ORs) with 95% confidence intervals (CIs) were reported. A p-value <0.05 was considered statistically significant.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee of Patna Medical College and Hospital. All participants and legally authorized representatives signed informed consent forms. Patient confidentiality and anonymity were respected during the study; all data collected were only utilized for research purposes.

Results

Demographic Characteristics of the Study Population: A total of 100 hospitalized patients with culture-confirmed Enterobacterales infections were included in the study.

The average age of the participants in the study was 49.8 ± 16.4 years (range 18–85 years). Most of the patients were in the age group of 41-60 years (36%) and the age group above 60 years (30%). The study population was predominantly male (62%), with females accounted for 38% of the sample, suggesting a higher prevalence of infections in males.

Table 1: Demographic Characteristics of the Study Population (n = 100)

Variable	Frequency (n)	Percentage (%)
Age Group (years)		
18–40	34	34.0
41–60	36	36.0
>60	30	30.0
Gender		
Male	62	62.0
Female	38	38.0
Mean Age (years)	**49.8 ± 16.4**	—

Distribution of Clinical Specimens: Urine was the most common clinical specimen (38% of all specimens). Blood cultures were obtained in 24%, pus specimens in 16%, sputum in 12% of the cases and other specimens such as wound swabs and endotracheal aspirates in 10%. This distribution is similar to typically realized in hospitalized patients, where UTIs and bloodstream infections are the leading causes of infection.

Table 2: Distribution of Clinical Specimens

Specimen Type	Frequency (n)	Percentage (%)
Urine	38	38.0
Blood	24	24.0
Pus	16	16.0
Sputum	12	12.0
Others*	10	10.0
Total	**100**	**100.0**

***Others include wound swabs and endotracheal aspirates.**

Distribution of Enterobacterales Isolates: Escherichia coli was the most frequently isolated bacterium (45%), followed by Klebsiella pneumoniae (32%). Enterobacter spp., (10%), Citrobacter spp., (8%) and Proteus spp., (5%) were the next most common isolates.

Table 3: Distribution of Enterobacterales Species

Bacterial Species	Frequency (n)	Percentage (%)
Escherichia coli	45	45.0
Klebsiella pneumoniae	32	32.0
Enterobacter spp.	10	10.0
Citrobacter spp.	8	8.0
Proteus spp.	5	5.0
Total	**100**	**100.0**

Prevalence of Carbapenem-Resistant Enterobacterales: Of the 100 Enterobacterales isolates that were tested, 32 (32.0%) were confirmed to be carbapenem-resistant using CLSI interpretive criteria. The other 68 (68.0%) isolates were carbapenem susceptible.

Table 4: Prevalence of Carbapenem-Resistant Enterobacterales

CRE Status	Frequency (n)	Percentage (%)
CRE Positive	32	32.0
CRE Negative	68	68.0
Total	**100**	**100.0**

Risk Factors Associated with CRE Infection: The results of logistic regression analysis showed several significant factors associated with CRE infection. Patients who were admitted to the ICU had over three times the possibility of developing CRE infection compared to those admitted to general wards (OR = 3.42, p = 0.008). Previous carbapenem exposure was the strongest predictor of CRE infection (OR = 4.68, p = 0.002). The other risk factors mechanical ventilation, urinary catheterization, diabetes mellitus, and hospital stay > 7 days were also independently associated with increased odds of CRE infection, with each factor having a statistically significant association ($p < 0.05$).

Table 5: Multivariable Logistic Regression Analysis of Risk Factors Associated with CRE Infection

Risk Factor	Odds Ratio (OR)	95% CI	p-value
ICU stay	3.42	1.38–8.49	0.008*
Previous carbapenem exposure	4.68	1.76–12.42	0.002*
Mechanical ventilation	2.89	1.17–7.13	0.021*
Urinary catheter	2.51	1.05–6.01	0.038*
Diabetes mellitus	2.27	1.01–5.12	0.047*
Hospital stay >7 days	3.11	1.29–7.50	0.011*

***Statistically significant ($p < 0.05$).**

Overall, the study showed a high prevalence of CRE in hospitalized patients. Escherichia coli and Klebsiella pneumoniae were the most prevalent organisms, and the following factors were identified as significant independent risk factors for CRE infection previous carbapenem exposure, admission to an ICU, extended hospital stays, invasive procedures, and diabetes mellitus.

Discussion

This study aims to explore the prevalence of CRE and its risk factors in the hospital setting at PMCH, Bihar. Overall, 32% of the isolates were carbapenem-resistant, suggesting a high level of carbapenem resistance in the study area. The most common pathogens isolated were Escherichia coli (45%) and Klebsiella pneumoniae (32%), both of which are known to be important contributors to healthcare-associated infections. ICU admission, prior carbapenem use, mechanical ventilation, urinary catheterization, diabetes mellitus, and greater hospital duration (more than 7 days) were the variables found to be important independent risk factors for CRE infection in a multivariable analysis.

Comparison with Previous Studies: The prevalence of CRE, as observed in the current study, is similar to that reported in multiple tertiary care hospitals throughout India, ranging from 20% to 40% of all hospital-acquired infections, especially in critically disease. Comparable studies conducted in South Asian countries have also shown that the resistance of Klebsiella pneumoniae and Escherichia coli to carbapenems is increasing, indicating universal antimicrobial selection pressure and infection prevention problems [14]. The prevalence of CREs has been reported to be lower in international studies carried out in Europe and North America, which may be attributed to more robust antimicrobial stewardship programs and stronger measures of infection control [15]. However, the predominant species of bacteria observed in this study, and the related clinical factors, are largely consistent with the worldwide evidence, highlighting the universal nature of

health-care-associated transmission of multidrug-resistant Enterobacterales.

There are several factors from this study that can explain why patients are at a greater risk for acquiring CRE infection. ICU patients are more likely to be exposed to invasive procedures, broad-spectrum antibiotics and long-term hospital stays, which all contribute to colonization and spread of resistant organisms. The use of carbapenems results in the selection of carbapenem-resistant strains. Similarly, the use of urinary catheters and mechanical ventilation may increase the risk of infection from the device because these devices may lead to bacterial colonization and biofilm formation. The prolonged hospital stay provides more time for cross-transmission of multidrug-resistant organisms and increased exposure to more antibiotics, all of which can help to persist and spread in health care settings.

Clinical Implications: The findings of this study highlight the importance of early laboratory detection of CRE and prompt implementation of infection prevention measures. To prevent the spread of resistant organisms, routine surveillance of high-risk patients, hand hygiene and isolation measures, and optimization of antimicrobial use (as antibiotic stewardship programs) are critical. Timely identification of colonized patients who are hospitalized for prolonged periods, have received prior carbapenems or have been hospitalized in the ICU may be associated with better clinical outcomes.

Strengths and Limitations: One of the strengths of this study is that clinical data were obtained from a tertiary care referral hospital using standardized microbiological methods and susceptibility testing methods recommended by the CLSI and in the real world. Additionally, the study offers valuable epidemiological data from Bihar, a setting where there is limited published data regarding CRE. Overall, the sample size was limited (100 patients), and the study was conducted in one centre, thus limiting the generalizability of the results. Furthermore, there was no molecular typing of antimicrobial resistance genes, and the limited study period might not reflect the seasonality or longer-term patterns of antimicrobial resistance.

Future Recommendations: Multicentre studies with greater numbers of patients are needed to further describe the epidemiology of CRE in any healthcare setting in the future. Incorporating molecular detection of carbapenems genes and genomic surveillance would help to better understand the mechanisms and dynamics of resistance. Continuous surveillance of antimicrobial resistance patterns along with enhanced antimicrobial stewardship and infection control measures will play a crucial role in controlling CRE and enhancing patient outcomes in India.

Conclusion

This study demonstrated a 32% prevalence of carbapenem-resistant Enterobacterales among hospitalized patients, highlighting a significant burden of antimicrobial resistance at PMCH, Patna. The risk factors that were found to be important were admission to the ICU, prior use of carbapenems, long hospital stay, urinary catheterization, mechanical ventilation and diabetes. The findings highlight the importance of ongoing surveillance, prompt laboratory identification, strong infection control and prevention strategies and effective antimicrobial stewardship programs to minimise the spread of CRE and enhance the outcomes for patients in tertiary healthcare facilities.

References

1. B. Guo et al., "Prevalence and risk factors of carbapenem-resistant Enterobacterales positivity by active screening in intensive care units in the Henan Province of China: A multi-centre cross-sectional study," Frontiers in Microbiology, vol. 13, Art. no. 894341, 2022.
2. V. A. T. Dinh et al., "Prevalence and risk factors for carbapenem-resistant Enterobacterales colonization in hospitalized children in a provincial hospital in Vietnam," Frontiers in Cellular and Infection Microbiology, vol. 16, Art. no. 1770367, 2026.
3. B. M. Aiesh et al., "Epidemiology and clinical characteristics of patients with carbapenem-resistant Enterobacterales infections: Experience from a large tertiary care center in a developing country," BMC Infectious Diseases, vol. 23, no. 1, Art. no. 644, 2023.
4. R. Moghnieh et al., "Epidemiology, risk factors, and prediction score of carbapenem resistance among inpatients colonized or infected with 3rd generation cephalosporin-resistant Enterobacterales," Scientific Reports, vol. 11, no. 1, Art. no. 14757, 2021.
5. N. Rebold et al., "Risk factors for carbapenem-resistant Enterobacterales clinical treatment failure," Microbiology Spectrum, vol. 11, no. 1, Art. no. e02647-22, 2023.
6. E. H. Yoo, H. L. Hong, and E. J. Kim, "Epidemiology and mortality analysis related to carbapenem-resistant Enterobacterales in patients after admission to intensive care units: An observational study," Infection and Drug Resistance, vol. 16, pp. 189-200, 2023.
7. M. Kedišaletše, D. Phumuzile, D. Angela, A. W., and M. N. F., "Epidemiology, risk factors, and clinical outcomes of carbapenem-resistant Enterobacterales in Africa: A systematic

review," Journal of Global Antimicrobial Resistance, vol. 35, pp. 297-306, 2023.
8. W. Wangchinda, K. Laohasakprasit, K. Lerdlamyong, and V. Thamlikitkul, "Epidemiology of carbapenem-resistant Enterobacterales infection and colonization in hospitalized patients at a university hospital in Thailand," Infection and Drug Resistance, vol. 15, pp. 2199-2210, 2022.
9. X. Chen, X. Wen, Z. Jiang, and Q. Yan, "Prevalence and factors associated with carbapenem-resistant Enterobacterales infection among hematological malignancies patients with CRE intestinal colonization," Annals of Clinical Microbiology and Antimicrobials, vol. 22, no. 1, Art. no. 3, 2023.
10. S. Mbele and S. D. Vasaikar, "Risk factors for carbapenem-resistant Enterobacterales infections: A case-control study," South African Family Practice, vol. 67, no. 1, Art. no. 6029, 2025.
11. K. H. Lee et al., "Prevalence of carbapenemase-producing Enterobacterales colonization and risk factor of clinical infection," Journal of Infection and Public Health, vol. 16, no. 11, pp. 1860-1869, 2023.
12. X. Chen, M. Zhou, Q. Yan, Z. Jian, W. Liu, and H. Li, "Risk factors for carbapenem-resistant Enterobacterales infection among hospitalized patients with previous colonization," Journal of Clinical Laboratory Analysis, vol. 36, no. 11, Art. no. e24715, 2022.
13. P. Fernandez Del Peloso, P. Kurtz, B. Brandão de Paula Antunes, L. dos Santos Lourenço Bastos, S. Hamacher, and F. A. Bozza, "Risk factors, impact on outcomes, and molecular epidemiology of infections caused by carbapenem-resistant Enterobacterales in intensive care patients: A multicenter matched case-control study in Brazil," Critical Care Science, vol. 37, Art. no. e20250237, 2025.
14. H. Yang et al., "Risk factors and molecular epidemiology of colonizing carbapenem-resistant Enterobacterales in pediatric inpatient in Shenzhen, China," Journal of Infection and Public Health, vol. 18, no. 1, Art. no. 102614, 2025.
15. V. Zambrano-Calderero, F. Vera-Álava, and M. Borges, "Risk factors associated with carbapenem-resistant Enterobacterales infections in hospitalized patients: A case-control study," Le Infezioni in Medicina, vol. 34, no. 1, p. 96, 2026.