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Microbial Epidemiology and Phenotypic Detection of Carbapenemase-Producing Gram-Negative Bacilli Causing Central Line-Associated Bloodstream Infections: A Prospective Study

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ABSTRACT

Background: Central line-associated bloodstream infection (CLABSI) is a major healthcare-associated infection in intensive care units, contributing significantly to morbidity, mortality, and antimicrobial resistance. Gram-negative bacilli (GNB), particularly carbapenem-resistant organisms, are emerging as important pathogens in CLABSI cases.

Aim: To determine the microbial epidemiology and phenotypic detection of carbapenemase-producing Gram-negative bacilli causing CLABSI in a tertiary care hospital.

Materials and Methods: This prospective observational study was conducted from January 2024 to December 2025 and included 245 ICU patients with suspected CLABSI. Blood cultures were processed using standard microbiological techniques and antimicrobial susceptibility testing was performed as per CLSI guidelines (2025). Carbapenemase production was detected using the Modified Carbapenem Inactivation Method (mCIM), EDTA-modified CIM (eCIM), and combined disk tests.

Results: CLABSI was confirmed in 35 out of 245 patients, giving an overall prevalence of 14.3% (35/245). Gram-negative bacilli predominated, accounting for 74.3% of isolates (26/35), with *Klebsiella pneumoniae* being the most common isolate at 30.8% (8/26), followed by *Acinetobacter baumannii* at 26.9% (7/26). High resistance was observed to cephalosporins and carbapenems, with 50.0% of Gram-negative isolates resistant to imipenem, meropenem, and ertapenem (13/26 each). Carbapenemase production was detected in 50.0% of isolates by mCIM (13/26), while 30.8% were metallo-β-lactamase producers by eCIM (8/26). Colistin and tigecycline retained the highest activity, with sensitivity rates of 96.2% (25/26) and 80.8% (21/26), respectively.

Conclusion: CLABSI in this study was predominantly caused by multidrug-resistant Gram-negative bacilli with high carbapenem resistance. Routine surveillance and rapid detection of carbapenemase producers are essential for guiding therapy and strengthening infection control practices.

Keywords: *CLABSI, Gram-negative bacilli, Carbapenemase, Multidrug resistance, mCIM, eCIM, Bloodstream infection.*

INTRODUCTION

Health-care-associated infection (HCAI) is perhaps the most important factor that adversely affects the performance and image of a hospital. One of the most common HCAIs is central line-associated bloodstream infection (CLABSI) which is indispensable in current intensive care treatment; also pose a greater risk of device related infections in comparison to any

other type of medical device[1].

Central venous catheters/line (CVCs/CVL) are integral to current-day intensive care practice as a tool for monitoring of hemodynamic variables, delivery of medications, vasopressors, blood products, parenteral nutrition and collection of blood samples. Most of these lines in acute care settings are the short-term percutaneous CVCs placed in the internal jugular, subclavian and femoral veins. Central line catheterization is sometimes complicated by bloodstream infections resulting in significant morbidity, mortality, antimicrobial resistance, increased duration of hospitalisation and additional medical costs[2].CLABSI is defined as a primary bloodstream infection occurring in a patient with a central line in place for more than 48 hours before the development of infection, and for which no other source of infection is identifiable. The Centers for Disease Control and Prevention (CDC) and the National Healthcare Safety Network (NHSN) emphasize rigorous surveillance and standardized definitions for accurate diagnosis and reporting. These infections are largely preventable, and their occurrence serves as a marker of hospital care quality.[3]

Monitoring the epidemiology of CLABSI is essential for infection control programs and improving patient outcomes. [4] Globally, CLABSI remains a significant cause of morbidity, mortality, and increased healthcare costs in hospitalized patients. In the Unites States, 2,50,000 catheter associated bloodstream infections are estimated to occur every year of which 60,000 occur in critically ill patients. Mortality from catheter associated bloodstream infection is estimated to be approximately 30,000 to 60,000 per year.[5] surveillance data show that CLABSI incidence in acute-care hospitals declined from about 1.6 per 1000 central-line days in 2009 to approximately 0.9 per 1000 central-line days in 2018. [6] Recent surveillance reports also estimate that ICUs in high-income countries typically report 0.6–1.4 CLABSI cases per 1000 central-line days, reflecting better infection prevention strategies and standardized monitoring systems. [7] India reports higher CLABSI rates compared with developed nations. A multicentric surveillance study conducted in hospitals across India from 2017–2024 reported 8629 CLABSI events with a pooled incidence of 8.83 per 1000 central-line days. The rate varied by ICU type, including 8.68 per 1000 central-line days in adult ICUs, 6.71 in paediatric ICUs, and 13.86 in neonatal ICUs. [8]

According to the Surveillance and Control of Pathogens of Epidemiological Importance (SCOPE) study, coagulase negative Staphylococcus accounted for 31% of bloodstream infections, whereas *Staphylococcus aureus* and *Enterococcus* account for 20% and 9% of infections respectively. Gram negative organisms causing central line associated bloodstream infection include *Escherichiacoli, Klebsiella* species, *Acinetobacter* species, *Pseudomonas aeruginosa* and gram-negative organisms accounted for 22% of intravascular device associated infections. In our study, we found a predominance of GNBs causing CLABSI, in contrast to GPCs, which predominate in studies from developed countries.[9] In another Indian study done in PGI, Chandigarh by Lakshmi11 et al. in the PICU, it was also found that GNBs predominated as a causative factor for nosocomial BSI. Thus, GNBs continue to dominate in developing countries where infection control practices are not optimal.

Carbapenems are some of the most effective options available for treating serious infections caused by Gram-negative antimicrobial-resistant organisms (AROs). Therefore, the emergence and spread of carbapenem resistance are significant public health concerns. [10] Carbapenemases are diverse enzymes that vary in their ability to hydrolyze carbapenems and other beta-lactams. Detection of carbapenemase is a crucial infection control issue because they are often associated with extensive antibiotic resistance, treatment failures and infection-associated mortality. [11] The WHO identified carbapenem-resistant Gram-negative bacteria (*i.e.*, *A. baumannii* complex*, P. aeruginosa*, and Enterobacterales) as critical-priority pathogens. Carbapenem-resistant *E. coli*, *K. pneumoniae*, *P. aeruginosa,* and *A. baumannii* complex were directly responsible for 181,000 deaths and played a role in 910,000 deaths during 2019.[10]This study aims to assess the microbial epidemiology and phenotypic detection of carbapenemase-producing Gram-negative bacilli causing CLABSI.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted from January 2024 to December 2025 in the Department of Microbiology, Index Medical College Hospital and Research Centre, Malwanchal University, Indore, in collaboration with the Intensive Care Unit (ICU), and included patients with central venous catheters (CVCs) who developed clinically suspected bloodstream infections and fulfilled the CDC/NHSN diagnostic criteria for Central Line-Associated Bloodstream Infection (CLABSI).

Study Population
A total of 245 eligible patients with clinically suspected CLABSI who met the predefined inclusion and exclusion criteria were enrolled consecutively during the study period. The sample size was determined based on the expected prevalence of CLABSI and the availability of eligible cases.

Inclusion Criteria
- Patients above 18 years of age admitted to the medicine Intensive Care Unit (ICU) during the study period with a central venous catheter for more than 48 hours.
- Patients who develop signs and symptoms of bloodstream infection after 48 hours of hospital/ICU admission.
- Patient willing to participate with informed consent in the study.

Exclusion Criteria
- Patients who have bloodstream infection present at the time of admission or within 48 hours of hospitalization (community-acquired infection).
- ICU Patients without central venous catheterization.
- Patients whose blood culture samples are contaminated or incomplete clinical data are available.

Specimen Collection
Aseptically collected blood samples were obtained from ICU patients suspected of having a central line-associated bloodstream infection (CLABSI) who exhibited clinical signs of infection 48 hours after the insertion of a central venous catheter. Two sets of blood cultures were collected: one from a peripheral vein and another from the central venous catheter. Each sample consisted of 8–10 mL of blood, which was inoculated into blood culture bottles and transported immediately to the microbiology laboratory.

The recorded data include: age, sex, type of intensive care unit, date of hospital admission, date of central venous catheter insertion, date of central venous catheter removal, date of blood sample collection, duration of catheterization, blood culture result, bacterial isolate, and antimicrobial susceptibility pattern.

Microbiological Processing
Positive blood culture bottles were cultured and incubated at 37°C using an automated blood culture system (BACTEC/BacT/ALERT) or conventional methods and were subcultured onto blood agar, MacConkey agar, after showing growth. The inoculated plates were incubated aerobically at 37°C for 18–24 hours, and bacterial isolates were identified based on colony morphology, Gram staining, motility, and standard biochemical tests (indole, citrate utilization, urease, triple sugar iron, and oxidase tests), along with automated identification techniques where applicable. Final identification was performed by conventional biochemical tests and/or automated identification systems such as VITEK 2, depending on availability.

Antimicrobial Susceptibility Testing
Antibiotic susceptibility testing was performed by Kirby–Bauer disk diffusion method on Mueller-Hinton agar, interpreted according to Clinical and Laboratory Standards Institute (CLSI) guidelines (latest edition) 2025.Antibiotics for Gram-negative isolates include ampicillin, piperacillin-tazobactam, ceftriaxone, ceftazidime, cefepime, imipenem, meropenem, amikacin, gentamicin, ciprofloxacin, and colistin, among others.**Carbapenems tested included:**Imipenem (10 µg), Meropenem (10 µg), Ertapenem (10 µg, if used).

Phenotypic Detection of Carbapenemase
Carbapenemase production among carbapenem-resistant Gram-negative bacilli was detected using the following phenotypic methods:

1. Modified Carbapenem Inactivation Method (mCIM)
- **A** 10 µg meropenem disk was immersed in a suspension of the test organism in tryptic soy broth and incubated at 35–37°C for 4 hours
- The disk was then placed on a lawn culture of Escherichia coli ATCC 25922 and incubated overnight at 37°C.
- ≤15 mm or colonies within zone → Positive (carbapenemase producer)
- ≥19 mm → Negative
- Intermediate results were interpreted as per CLSI criteria.

2. EDTA-Modified Carbapenem Inactivation Method (eCIM)
Used to differentiate metallo-β-lactamase (MBL) producers:

- EDTA was added to one tube while another served as control
- Difference in zone diameter:
- ≥5 mm increase with EDTA → MBL producer
- <5 mm difference → serine carbapenemase

3. Combined Disk Test (CDT)

- Imipenem (10 µg) disk alone and imipenem + EDTA disk were placed on MHA
- Increase in zone diameter ≥7 mm indicated MBL production

Definitionof Carbapenemase Producers

Isolates were categorized as carbapenemase producers based on:

- Positive mCIM test (primary confirmatory test)
- Supporting phenotypic tests (eCIM/CDT/MHT where applicable)

Data Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS statistics version no. 29. Categorical variables were expressed as frequencies and percentages. Associations between Categorical variables variables were analysed using Chi-square test or Fisher's exact test as appropriate. A p-value <0.05 was considered statistically significant.

Ethical approval

The study received clearance from the Institutional Ethics Committee of Index Medical College Hospital and Research Center, affiliated with Malwanchal University, under approval number MU/Research/EC/Ph.D./2023/034. Patient confidentiality was preserved during the study. Informed consent was obtained from participants, or a waiver was granted by the ethics committee, if relevant.

RESULTS

Study Population

A total of 245 ICU patients with clinically suspected central line-associated bloodstream infection (CLABSI) were included in the study. Among them, CLABSI was confirmed in 35 patients, giving an overall positivity rate of 14.3% (35/245), while 210 patients were CLABSI-negative, accounting for 85.7% (210/245) of the study population.

Table 1. Distribution of CLABSI Cases

CLABSI status	Number of patients	Percentage
CLABSI positive	35	14.29%
CLABSI negative	210	85.71%
Total	**245**	**100%**

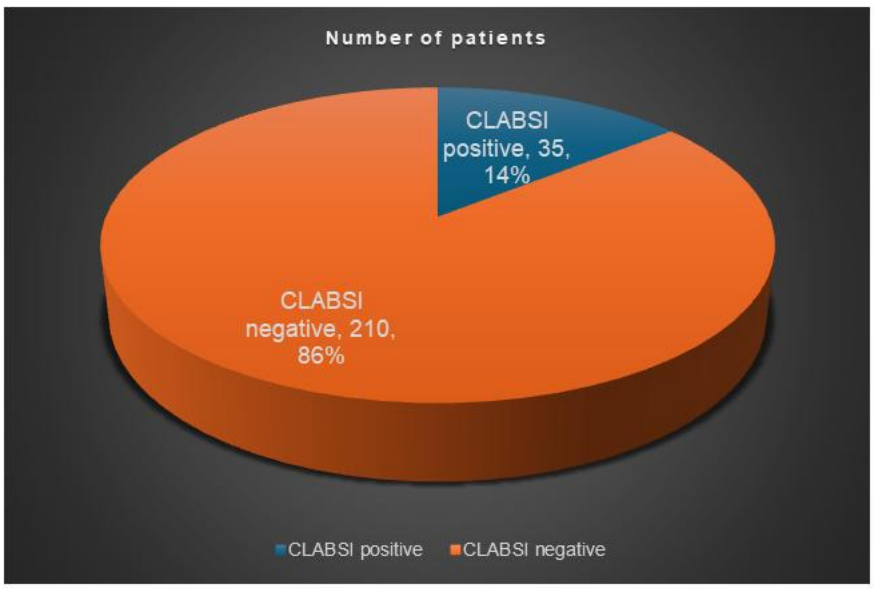

Figure 1. Distribution of CLABSI Cases

Demographic Epidemiology

A total of 245 ICU patients with clinically suspected central line-associated bloodstream infection (CLABSI) were included in the study. Among them, CLABSI was confirmed in 35 patients, giving an overall positivity rate of 14.3% (35/245), while 210 patients were CLABSI-negative, accounting for 85.7% (210/245) of the study population.

Table 2: Sex-wise distribution of Central line associated blood stream infection (CLABSI)

Sex	Total cases	Positive cases	Prevalence within group (%)
Female	113	12	10.6
Male	132	23	17.4

Table 3: Age-wise distribution of CLABSI

Age group (years)	Total cases (n=245)	Positive cases (n=35)	Prevalence within group (%)
≤20	9	2	22.2
21–40	69	8	11.6
41–60	78	8	10.3
61–80	71	15	21.1
>80	18	2	11.1

The maximum number of patients were admitted in MICU, followed by SICU, CCU, and Respiratory ICU. However, the highest CLABSI positivity rate was observed in CCU, where 12 out of 43 patients (27.91%) were CLABSI positive.

Table 4. ICU-wise distribution of CLABSI

ICU type	Total patients	CLABSI positive	Positivity rate
MICU	131	11	8.40%
SICU	45	8	17.78%
CCU	43	12	27.91%
Respiratory ICU	26	4	15.38%
Total	**245**	**35**	**14.29%**

The correlation between ICU type and CLABSI status was statistically significant ($p = 0.013$), indicating variability in CLABSI incidence across various ICU environments.

Microbial Epidemiology of CLABSI

Among the 35 microbiologically confirmed CLABSI cases, Gram-negative bacilli predominated (26/35; 74.3%), while Gram-positive cocci accounted for 9 (25.7%) isolates.

Table 5. Gram Stain Distribution

Gram Reaction	Number	Percentage (%)
Gram-negative bacilli	26	74.3
Gram-positive cocci	9	25.7
Total	**35**	**100**

Table 6. Epidemiological Distribution of Gram-negative Bacilli (n = 26)

Gram-negative Organism	Number	Percentage (%)
Klebsiella pneumoniae	8	30.8
Acinetobacter baumannii	7	26.9
Escherichia coli	5	19.2
Pseudomonas aeruginosa	5	19.2
Proteus mirabilis	1	3.9
Total	**26**	**100**

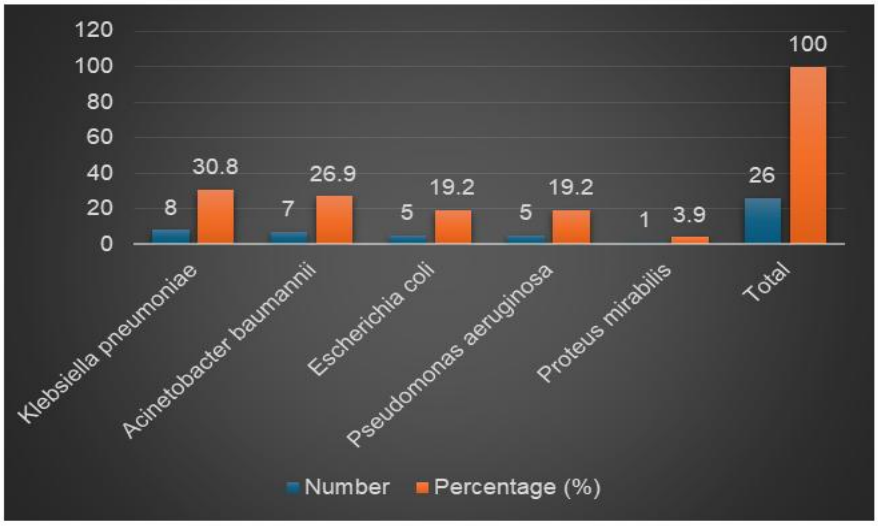

Figure 2. Epidemiological Distribution of Gram-negative Bacilli (n = 26)

- Among the 26 Gram-negative bacilli isolated, Klebsiella pneumoniae was the predominant pathogen, accounting for 30.8% (8/26), followed by Acinetobacter baumannii at 26.9% (7/26). Escherichia coli and Pseudomonas aeruginosa each accounted for 19.2% (5/26) of Gram-negative isolates, while Proteus mirabilis represented 3.9% (1/26).%.

Table 7. Antibiotic Susceptibility Pattern of Gram-negative Bacilli (n = 26)

Antibiotic	Resistant n (%)	Intermediate n (%)	Sensitive n (%)
Ampicillin	21 (80.8)	0	0*
Piperacillin–Tazobactam	9 (34.6)	6 (23.1)	11 (42.3)
Ceftriaxone	21 (80.8)	0	0*
Cefuroxime	18 (69.2)	1 (3.8)	7 (26.9)
Gentamicin	7 (26.9)	6 (23.1)	13 (50.0)
Levofloxacin	14 (53.8)	0	12 (46.2)
Ciprofloxacin	14 (53.8)	2 (7.7)	10 (38.5)
Trimethoprim–Sulfamethoxazole	15 (57.7)	0	11 (42.3)
Amikacin	10 (38.5)	9 (34.6)	7 (26.9)
Cefepime	16 (61.5)	2 (7.7)	8 (30.8)
Tetracycline	12 (46.2)	0	14 (53.8)
Aztreonam	17 (65.4)	1 (3.8)	8 (30.8)
Ceftazidime	20 (76.9)	0	6 (23.1)
Meropenem	13 (50.0)	0	13 (50.0)
Ertapenem	13 (50.0)	0	13 (50.0)
Imipenem	13 (50.0)	1 (3.8)	12 (46.2)
Tigecycline	3 (11.5)	2 (7.7)	21 (80.8)
Colistin	1 (3.8)	0	25 (96.2)

Antimicrobial susceptibility testing of the 26 Gram-negative isolates revealed high resistance to third-generation cephalosporins and β-lactam antibiotics. Resistance was highest against ampicillin and ceftriaxone, with 80.8% resistance each (21/26), followed by ceftazidime at 76.9% (20/26). Substantial resistance was also observed against cefuroxime at 69.2% (18/26), aztreonam at 65.4% (17/26), and cefepime at 61.5% (16/26). Fluoroquinolone resistance was observed in 53.8% of isolates for both levofloxacin and ciprofloxacin (14/26 each). Carbapenem resistance was 50.0% for meropenem, ertapenem, and imipenem (13/26 each), with one isolate showing intermediate susceptibility to imipenem. Colistin and tigecycline demonstrated the highest in vitro activity against Gram-negative bacilli, with susceptibility rates of 96.2% (25/26) and 80.8% (21/26), respectively.

Carbapenem Resistance Profile

Table 8. Carbapenem Resistance among Gram-negative Bacilli

Antibiotic	Resistant	Percentage (%)
Imipenem	13	50.0
Meropenem	13	50.0
Ertapenem	13	50.0

Phenotypic Detection of Carbapenemase
Of the 26 Gram-negative isolates, 13 (50.0%) were positive by the Modified Carbapenem Inactivation Method (mCIM), indicating carbapenemase production.

Table 9. mCIM Results (Gram-negative isolates, n = 26)

mCIM Result	Number	Percentage (%)
Positive	**13**	**50.0**
Negative	**13**	**50.0**

eCIM Results
Among the Gram-negative isolates tested, 8 (30.8%) were positive by eCIM, indicating metallo-β-lactamase (MBL) production.

Table 10. eCIM Results

eCIM Result	Number	Percentage (%)
Positive (MBL)	**8**	**30.8**
Negative	**18**	**69.2**

DISCUSSION

Central line-associated bloodstream infection (CLABSI) remains one of the most important healthcare-associated infections worldwide, particularly among critically ill patients requiring prolonged central venous catheterization. It contributes significantly to increased morbidity, mortality, prolonged hospitalization, and healthcare costs (O'Grady et al., 2011; Mermel, 2011). [12,13] The present prospective study evaluated the microbial epidemiology and carbapenemase production among Gram-negative bacilli causing CLABSI in a tertiary care teaching hospital in Central India.

In the present study, 35 of 245 clinically suspected patients were culture positive for CLABSI, giving an overall positivity rate of **14.29%**. This finding is comparable to studies conducted in Indian tertiary care hospitals by Rosenthal et al., who reported higher CLABSI rates in developing countries than in high-income nations because of limited infection-control resources and higher device utilization (Rosenthal et al., 2023).[14] Similarly, the CDC National Healthcare Safety Network (NHSN) has demonstrated that implementation of catheter care bundles significantly reduces CLABSI incidence in developed countries (CDC, 2024).[15]

Male patients constituted 23 (**65.7%)** of CLABSI cases in the present study. Similar male predominance has been reported by Blot et al., who suggested that greater ICU admission rates, underlying comorbid illnesses, and increased exposure to invasive procedures contribute to the higher incidence among males (Blot et al., 2014).[16] Furthermore, the highest prevalence was observed among patients aged **61–80 years**, which agrees with the findings of Mermel (2011), who reported advanced age as an independent risk factor for catheter-related bloodstream infections owing to impaired immunity, multiple comorbidities, and prolonged hospitalization.[13]

The Coronary Care Unit (CCU) demonstrated the highest CLABSI positivity (27.91%), and the association between ICU type and CLABSI occurrence was statistically significant (p=0.013). Similar observations have been reported by the International Nosocomial Infection Control Consortium (INICC), which documented variability in CLABSI incidence among different ICU settings depending upon catheter utilization ratio, severity of illness, and adherence to infection prevention bundles (Rosenthal et al., 2023).[14]

Microbiologically, Gram-negative bacilli accounted for 26 (74.3%) of all isolates, whereas Gram-positive cocci constituted only 25.7%. This predominance of Gram-negative organisms is consistent with several Indian studies but differs from surveillance reports from Europe and North America, where coagulase-negative staphylococci and *Staphylococcus aureus* remain the principal pathogens (O'Grady et al., 2011).[12]Similar observations were reported by Mehta et al. from India, who demonstrated that Gram-negative bacilli predominate in ICU-associated bloodstream infections because of environmental persistence, biofilm formation, and widespread antimicrobial resistance (Mehta et al., 2014).[17]

Among Gram-negative bacilli, Klebsiella pneumoniae 26 (30.8%) was the predominant pathogen followed by Acinetobacter baumannii 7 (26.9%), Escherichia coli 5 (19.2%), and Pseudomonas aeruginosa 5 (19.2%). Comparable findings were reported by the Indian Council of Medical Research (ICMR) antimicrobial resistance surveillance network, which identified *Klebsiella pneumoniae* and *Acinetobacter baumannii* as the leading causes of multidrug-resistant bloodstream infections in Indian ICUs (Veeraraghavan et al., 2018).[18] Their predominance is largely attributed to biofilm formation on intravascular devices, production of multiple virulence factors, and acquisition of resistance genes through plasmids and transposons (Logan & Weinstein, 2017).[19]

The antimicrobial susceptibility pattern observed in the present study revealed alarmingly high resistance to third-generation cephalosporins, with resistance to ceftriaxone (80.8%), ceftazidime (76.9%), and cefepime (61.5%). Similar resistance profiles have been documented by Veeraraghavan et al. in the ICMR surveillance programme, which demonstrated extensive dissemination of extended-spectrum β-lactamase (ESBL)-producing Enterobacterales in India.[18] High fluoroquinolone resistance observed in the present study (53.8%) also agrees with findings reported by Magiorakos et al., who emphasized increasing multidrug resistance among healthcare-associated Gram-negative pathogens.[20]

A particularly important finding of this study was that 50% of Gram-negative isolates were resistant to carbapenems. Comparable carbapenem resistance rates have been reported from tertiary care hospitals across India by Nordmann et al., who highlighted carbapenem-resistant Enterobacterales as one of the most serious emerging threats to global public health because of limited therapeutic options and high mortality.[21] Similarly, the World Health Organization has categorized carbapenem-resistant *Klebsiella pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa* as critical-priority pathogens requiring urgent research and development of new antimicrobial agents (WHO, 2024).[22]

Phenotypic detection using the Modified Carbapenem Inactivation Method (mCIM) demonstrated carbapenemase production in 50% of Gram-negative isolates. This finding supports the recommendation of the Clinical and Laboratory Standards Institute (CLSI), which recognizes mCIM as a sensitive and specific phenotypic method for routine laboratory detection of carbapenemase-producing Gram-negative bacilli (CLSI M100, 2025).[23] Similar observations have been reported by Tamma and Simner, who demonstrated excellent sensitivity of mCIM for detecting carbapenemase-producing Enterobacterales and non-fermenters.[24]

The EDTA-modified Carbapenem Inactivation Method (eCIM) identified 30.8% of isolates as metallo-β-lactamase (MBL) producers. This observation is consistent with reports by van Duin and Doi, who documented widespread dissemination of New Delhi Metallo-β-lactamase (NDM) among Enterobacterales in South Asia.[25]The increasing prevalence of MBL-producing organisms is clinically important because these enzymes hydrolyze almost all β-lactam antibiotics except aztreonam and are frequently associated with mobile genetic elements that facilitate rapid horizontal gene transfer.[25]

Despite widespread multidrug resistance, colistin remained active against 96.2% of isolates, followed by tigecycline (80.8%). Similar susceptibility patterns have been reported by Falagas et al., who identified polymyxins as among the few remaining therapeutic options for carbapenem-resistant Gram-negative infections while cautioning against their indiscriminate use because of emerging plasmid-mediated colistin resistance (Falagas et al., 2010).[26]

There should be continuous further research necessary to monitor the spread of carbapenem-resistant OXA-type lactamase genes from A. baumannii in hospital settings since they are becoming a significant cause of carbapenem resistance. Effective infection control practises and strict guidelines for the use of antibiotics should be in place [27].

Overall, the findings of the present study underscore the urgent need for continuous microbiological surveillance, routine phenotypic detection of carbapenemase-producing organisms, implementation of evidence-based CLABSI prevention bundles, and robust antimicrobial stewardship programmes. Early identification of carbapenemase-producing Gram-negative bacilli will facilitate appropriate antimicrobial therapy and effective infection-control interventions, thereby reducing the transmission of multidrug-resistant pathogens within intensive care units.

CONCLUSION

This prospective study demonstrated that Gram-negative bacilli were the predominant pathogens causing central line-associated bloodstream infections (CLABSI), with Klebsiella pneumoniae and Acinetobacter baumannii being the most frequently isolated organisms. A high prevalence of multidrug resistance and 50% carbapenem resistance among Gram-negative isolates highlights the increasing threat of antimicrobial resistance in intensive care units. The Modified Carbapenem Inactivation Method (mCIM) and EDTA-modified Carbapenem Inactivation Method (eCIM) proved to be useful phenotypic methods for detecting carbapenemase-producing organisms. These findings emphasize the need for continuous microbiological surveillance, routine carbapenemase detection, strict adherence to CLABSI prevention bundles, and effective antimicrobial stewardship programmes to improve patient outcomes and limit the spread of multidrug-resistant pathogens.

LIMITATIONS

This study was conducted at a single tertiary care centre with a relatively small sample size, which may limit the generalizability of the findings. In addition, only phenotypic methods (mCIM and eCIM) were used for carbapenemase detection, and molecular characterization of resistance genes was not performed.

DECLARATIONS

Ethical approval

The study received clearance from the Institutional Ethics Committee of Index Medical College Hospital and Research Center, affiliated with Malwanchal University, under approval number MU/Research/EC/Ph.D./2023/034.

Conflicts of interest: There is no any conflict of interest associated with this study.

Consent to participate: There is consent to participate.

Consent for publication: There is consent for the publication of this paper.

Authors & contributions: Author equally contributed the work.

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