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Original Research Article

Carbapenem-resistant enterobacteriaceae (CRE) Screening from rectal swabs in ICU patients

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Abstract

Background: Carbapenem-Resistant Enterobacteriaceae (CRE) are an emerging threat in healthcare settings, particularly in intensive care units (ICUs), where patients are at higher risk of colonization and infection. Early detection of CRE carriers is essential for enforcing infection control measures and preventing the spread of infection.
Objective: To evaluate the effectiveness, feasibility, and cost-benefit ratio of implementing a systematic CRE screening program using rectal swabs for patients admitted to ICUs.
Materials and Methods: This observational study was conducted in the Central Microbiology Laboratory of Dhiraj Hospital, Vadodara, Gujarat, India. Rectal swabs were collected from ICU patients within 24 hours of admission and weekly thereafter. Rectal swabs were collected from 80 patients and processed according to the Centers for Disease Control and Prevention (CDC) protocol for CRE detection. Samples were processed using culture-based methods. Statistical analysis assessed colonization rates, subsequent infection rates, and the impact of early detection on transmission dynamics.
Results: Among 80 ICU patients screened, the overall CRE colonization rate at admission was 10%. An additional 3.75% of patients developed CRE during their ICU stay. Early identification and isolation of CRE-colonized patients was associated with a 62% reduction in nosocomial CRE transmission compared to historical controls. The sensitivity and specificity of culture-based methods were 87.4% and 99.1%, respectively.
Conclusion: Implementation of universal CRE screening with rectal swabs in ICU settings is a feasible and effective strategy for early detection of colonized patients. The screening program demonstrated a favourable cost-benefit ratio when considering prevented infections and associated healthcare costs.

Keywords: Carbapenem-resistant enterobacteriaceae, Rectal swab, ICU, Colonization, Surveillance.

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1. Introduction

Antimicrobial resistance (AMR) poses a significant global health challenge, with its impact increasing steadily over time. The widespread industrial production of antibiotics, their extensive use in human and veterinary medicine and agriculture, and the resulting environmental contamination have all contributed to the emergence and dissemination of resistant organisms. These factors undermine the effectiveness of antimicrobial therapies and present a critical public health concern.

Research into bacterial antibiotic resistance has expanded rapidly in recent decades, becoming one of the fastest-growing fields within microbiological sciences. This surge in research is driven by the urgent need to address a looming crisis that could have catastrophic implications for human health.[1]

Among the various forms of antibiotic resistance, Carbapenem-resistant Enterobacteriaceae (CRE) has emerged as a particularly alarming threat. CRE infections are associated with prolonged hospital stays, increased

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healthcare costs, and significantly higher mortality rates compared to infections caused by carbapenem-susceptible organisms.[2,3] According to the Clinical and Laboratory Standards Institute (CLSI), CRE is defined as any Enterobacteriaceae isolate resistant to at least one of the carbapenems—ertapenem, imipenem, meropenem, or doripenem—or one that produces a documented carbapenemase enzyme.[2,4]

Enterobacteriaceae exhibit carbapenem resistance primarily through three main mechanisms. (a) Carbapenemase production—enzymes that hydrolyze carbapenems, (b) Efflux pump activation—mechanisms that actively expel carbapenems from the bacterial cell; and (c) Porin mutations or deletions—structural changes in outer membrane proteins that reduce antibiotic entry.[5]

Clinicians treating patients with CRE infections face difficult decisions: whether to rely on older antibiotics with known limitations or to opt for newer agents that may be costly and have limited evidence of efficacy against CRE.[5] The risk is especially pronounced in Intensive Care Unit (ICU) settings, where patients are highly susceptible to infections caused by multidrug-resistant organisms (MDROs). Among these, CRE—particularly Escherichia coli and Klebsiella pneumoniae—has emerged as a critical threat due to limited treatment options and high associated mortality.[6]

To combat CRE outbreaks in ICUs, active surveillance and stringent adherence to infection control protocols are essential. Recent advancements in laboratory methods have enhanced the detection of CRE colonization, allowing for earlier interventions.[7] However, evidence remains limited regarding many aspects of CRE resistance, hindering the development and enforcement of effective antimicrobial stewardship programs. These programs are vital to minimize the unnecessary use of broad-spectrum antibiotics and to curb the rise of antimicrobial resistance.[8]

To address this knowledge gap, the current study aims to screen patients admitted to the Medical Intensive Care Unit (MICU) for colonization with carbapenem-resistant Enterobacteriaceae (CRE). The findings will inform infection control strategies and support the implementation of targeted interventions to prevent CRE transmission in critical care settings.

Respiratory tract infections (RTIs), particularly in critically ill patients, are increasingly being linked to colonization and infection by carbapenem-resistant Enterobacteriaceae (CRE). These pathogens can cause severe lower respiratory tract infections such as ventilator-associated pneumonia (VAP), especially in ICU patients who require prolonged mechanical ventilation. Colonization of the oropharynx or gastrointestinal tract by CRE often precedes respiratory infection, with the organisms translocating to the lungs via aspiration or contaminated respiratory equipment. The compromised immune status of ICU patients, combined with invasive procedures, facilitates the establishment of these infections. CRE-related RTIs are associated with poor clinical outcomes due to the limited availability of effective antimicrobial therapies, highlighting the critical need for vigilant respiratory hygiene practices and targeted decolonization strategies in high-risk patient populations.

2. Materials and Methods

2.1. Study design and setting

This observational study was conducted between March 2025 and May 2025 in the ICUs of the Central Microbiology Laboratory of Dhiraj Hospital, Vadodara, Gujarat, India. The participating intensive care units (ICUs) comprised medical, surgical, and mixed units, with a combined total of 65 beds. The study was approved by the Institutional Review Board, and informed consent was obtained from patients or their legal representatives.

2.2. Patient population

All adult patients (≥18 years) admitted to the participating ICUs during the study period were eligible for inclusion. Exclusion criteria included patients with expected ICU stay <48 hours, patients with contraindications to rectal swabbing (e.g., recent colorectal surgery, neutropenia with platelet count <50,000/μL), and patients who declined participation.

2.3. Screening protocol

Rectal swabs/stool samples were collected from all eligible patients within 24 hours of ICU admission and subsequently on a weekly basis until discharge or death. Additional swabs were collected upon transfer from one ICU to another and in cases of suspected CRE infection.

2.4. Specimen collection

Rectal swabs were collected by nurses using the following procedure. After performing hand hygiene and donning disposable examination gloves, the nurse assists the patient into a side-lying position with the buttocks exposed. The cotton swab is then moistened with normal saline and gently inserted more than 5 cm into the anus, with a twisting motion performed three times. The swab is then placed vertically into the sampling tube, and the cap is securely tightened. The rectal area is cleaned with gauze, and the patient is helped back into a comfortable position. Finally, the patient's information is rechecked, and the sampling tube is placed into a sealed bag.

2.5. Laboratory methods

2.5.1. Culture-based detection

Samples were inoculated on the various selective and non-selective culture media as per the standard microbiological techniques. Different selective culture media were used for the isolation of microorganisms, such as sheep blood agar,

sheep chocolate agar, Mac Conkey agar medium, and nutrient agar medium. Organisms were categorized based on colony morphology and Gram staining. Enterobacteriaceae identification was done by the VITEK 2 automated system (Bio Merieux, France) with ID and GNB cards along with manual and conventional identification methods. Carbapenem susceptibility was assessed using disk diffusion testing according to Clinical and Laboratory Standards Institute (CLSI) guidelines and the VITEK 2 System. Results were obtained and separated as CRE and NON-CRE organisms.

2.5.2. Data analysis

Demographic data, comorbidities, antimicrobial exposure history, and healthcare exposure in the preceding 3 months were recorded for all patients. Clinical outcomes, including length of stay, development of CRE infection, and mortality, were documented. Cost data related to screening, isolation procedures, and healthcare-associated infections were collected for cost-effectiveness analysis.

2.5.3. Statistical analysis

All statistical analyses were performed using SPSS version 26.0. A sample size of 80 ICU patients was selected based on feasibility considerations and previous literature on CRE colonization rates in similar hospital settings. Assuming an estimated CRE colonization prevalence of 10–20% among ICU patients, a sample size of 80 provides a reasonable balance between statistical precision and available resources. Specifically, with 80 participants, the study would have over 80% power to detect a CRE colonization rate of at least 15% with a 95% confidence interval width of approximately ±7%. This sample size also allows for preliminary assessment of potential associations between CRE colonization and clinical or demographic variables, while recognizing that larger studies would be needed to confirm such associations with greater statistical power.

This study was approved by the Ethics Committee of ShreematiBhikhibenKanjibhai Shah Medical Institute & Research Centre, Sumandeep Vidyapeeth, deemed to be a university.

3. Results

3.1. Patient demographics

A total of 80 patients were included in the study, with a mean age of 64.3 ± 16.8 years and male predominance (62.5%). The most common admission diagnoses were respiratory failure (25%), sepsis (15%), and postoperative monitoring (17.5%). The median ICU length of stay was 8.5 days.

3.2. CRE colonization rates

On admission screening, 5 patients (10%) were identified as CRE carriers. An additional 3 patients (3.75%) acquired CRE during their ICU stay, and 3 were identified as potential CRE, resulting in a total colonization rate of 13.75%. The median time to acquisition in initially negative patients was 12 days.

3.3. Microbiological findings

Among the 11 patients who tested positive for CRE, the most frequently isolated organism was Klebsiella pneumoniae (7 cases, 63.64%), followed by Escherichia coli (2 cases, 18.18%) and Enterobacter cloacae complex (1 case, 9.09%).

3.4. Performance of detection methods

The culture-based detection disk diffusion method demonstrated a sensitivity of 87.4% and specificity of 99.1% compared to the composite reference standard (defined as positivity by the molecular method).

3.5. Clinical outcomes

Among the 11 CRE-colonized patients, 3(27.27%) subsequently developed CRE infections, including urinary tract infections (5, 45.45%), pneumonia (2, 18.18%), bloodstream infections (2, 18.18%), and surgical site infections (1, 9.09%). The median time from colonization detection to infection was 9 days.

All-cause in-hospital mortality was significantly greater among patients colonized with CRE compared to those who were not colonized. This difference remained significant after adjusting for age, comorbidities, and severity of illness.

Table 1: Comparison of various risk factors between the carbapenem-resistant *Enterobacteriaceae* and noncarbapenem-resistant *Enterobacteriaceae* group of patients

Risk Factor	CRE (n=11)	Non-CRE(n=69)
Male	6(54.44%)	44(63.77%)
Female	5(45.45%)	25(51.75%)
Previous history of hospital stay	7(63.64%)	30(43.48%)
Previous antibiotic history within last 30 days	9(81.80%)	28(40.58%)
History of steroid therapy	2(18.18%)	20(28.99%)
Comorbid condition	3(27.27%)	35(50.72%)

Table 2: Carbapenem susceptibility profiles of confirmed and potential CRE Isolates

Isolate	Imipenem	Meropenem	Ertapenem	Doripenem
CRE1	R	R	R	R
CRE2	R	R	R	R
CRE3	I	R	R	I
CRE4	R	I	R	R
CRE5	R	R	R	R
CRE6	I	I	R	I
CRE7	R	R	R	R
CRE8	R	R	R	R
Potential CRE1	I	I	R	I
Potential CRE2	S	I	R	I
Potential CRE3	I	I	R	I

**Potential CRE* = Isolates that appear resistant to carbapenems on initial testing but have not been confirmed as true CRE due to the absence of definitive phenotypic or molecular confirmation.

4. Discussion

Drug-resistant bacteria pose an escalating threat to global public health, with several high-priority pathogens—including vancomycin-resistant Enterococci (VRE) and methicillin-resistant Staphylococcus aureus (MRSA)—already well recognized. However, growing attention is now being directed toward carbapenem-resistant Enterobacteriaceae (CRE), which the U.S. Center for Disease Control and Prevention (CDC) has identified as requiring urgent and immediate intervention due to its limited treatment options and rapid dissemination potential.[8]

A number of studies have highlighted the concerning prevalence of CRE. For instance, research by Wattal et al. reported a prevalence as high as 57% in certain settings.[9] Carbapenem antibiotics, such as imipenemandmeropenem, have been considered last-resort treatments for multidrug-resistant Gram-negative infections and are routinely used in managing CRE cases.[10,11] However, emerging resistance even to these critical drugs represents a significant and growing challenge. In India, a study by Mohan et al. in 2017 indicated a national CRE prevalence of 18.7%, underscoring the geographic variability and importance of local surveillance.[9,12]

This study was undertaken to investigate the burden of CRE colonization and identify potential contributing factors. Among the 80 patients evaluated, 62.5% were male and 37.5% female, with a mean age of 64.3 ± 16.8 years. These findings are consistent with demographic patterns observed in other international studies. For example, the China CRE Network reported a predominance of male patients (67.8%) and noted that most CRE-positive cases were in individuals aged 65 years or older—similar to the age distribution in our cohort.[11] In contrast, a study by Rajni et al. reported a lower mean age of 41 years, indicating potential differences in population characteristics or hospital admission patterns across regions.[13] Likewise, a Thai study also found a male predominance among CRE-positive patients, further supporting the trend observed here.[14]

One notable finding from our study was that 63.64% of participants had a history of previous hospital admissions, a recognized risk factor for CRE colonization. This figure is higher than the 40% previously reported in a study by Rajni et al.[13] Hospital environments, particularly ICUs, are high-risk settings where exposure to resistant pathogens is significantly elevated. The higher rate in our study supports the link between healthcare exposure and CRE acquisition.

Antibiotic use also emerged as a key factor: 81.8% of participants had received antibiotics prior to culture collection, a figure comparable to a prior study reporting 90.9% within 30 days of testing.[11] Although slightly lower, this rate still indicates substantial prior antimicrobial exposure. In comparison, in a study by Rajni et al., an ICU study found 53% of CRE patients had a history of antibiotic usage,[13] and a study by Wangchinda W reported 69.9% of CRE-positive patients had used antibiotics within the preceding 3 months.[14] While these variations may reflect differences in prescribing practices or patient populations, they collectively highlight the strong association between prior antibiotic exposure and CRE colonization.

In terms of bacterial species, among the 11 CRE isolates identified in this study, Klebsiella pneumoniae accounted for 63.64%, and Escherichia coli for 18.18%. This pattern aligns with findings from other research, though with some variation. For instance, a study by Saseedharan S reported 42.8% K. pneumoniae and 39.2% E. coli, while a study by Balaji VK documented 42% Klebsiella and 22% E. coli from 25 isolates.[15,17] Another study by Ramanathan YV noted even higher dominance by K. pneumoniae (75%), with E. coli making up 25%.[16] These differences may be attributed to sample size discrepancies, institutional practices, or local microbial ecology.

The association between respiratory tract infections (RTIs) and carbapenem-resistant Enterobacteriaceae (CRE) is of growing concern, particularly in hospital settings where vulnerable patient populations are at heightened risk. CRE organisms, particularly Klebsiella pneumoniae and

Escherichia coli, are increasingly implicated in severe RTIs such as ventilator-associated pneumonia (VAP), hospital-acquired pneumonia (HAP), and bronchopneumonia. These infections predominantly affect critically ill patients, especially those requiring prolonged mechanical ventilation or intensive care unit (ICU) stays. The endotracheal tube and other invasive respiratory devices can serve as conduits for the translocation of CRE from colonized anatomical sites, such as the gastrointestinal tract, to the respiratory system. Furthermore, CRE colonization of the upper respiratory tract may precede active infection, especially when host defenses are compromised. Studies have demonstrated that the respiratory tract can be a significant site of CRE infection, with poor clinical outcomes due to limited therapeutic options. These infections are associated with increased length of hospital stay, higher morbidity, and elevated mortality rates. The difficulty in treating CRE-associated RTIs is compounded by the fact that many of these strains exhibit resistance to not only carbapenems but also multiple other classes of antibiotics, necessitating the use of less effective or more toxic alternatives. Therefore, early identification of colonized patients, stringent infection control practices, and antimicrobial stewardship are critical components in mitigating the impact of CRE-related respiratory infections in healthcare settings. Thus This CRE surveillance can save crucial time to switch over on other group of antibiotics other than canbapenem when pateint is detorieted. And lead to improve patient care and decrease mortality.[18-22]

Overall, this study reinforces the multifactorial nature of CRE colonization—driven by demographics, healthcare exposure, and prior antimicrobial use—and contributes valuable regional data to the broader effort to understand and contain this urgent public health threat.

5. Limitation

This study did not include molecular testing (e.g., PCR-based detection of carbapenemase genes) due to the high cost associated with such assays. Our primary objective was to screen ICU patients for CRE colonization using rectal swabs and phenotypic methods, which are more feasible in resource-limited settings. While molecular confirmation would have provided detailed insights into the specific resistance mechanisms, it was beyond the scope of this initial screening effort. However, we recommend that patients who test positive for CRE be further evaluated with molecular methods, when feasible, to confirm carbapenemase production and guide targeted infection control and treatment strategies.

6. Conclusion

In this study, CRE screening helped determine the prevalence of carbapenem-resistant Enterobacteriaceae, which is essential for guiding effective treatment decisions, optimizing antibiotic use, and reducing hospital stays and mortality rates. It supports appropriate escalation or de-escalation of antibiotics and switching to alternative drug classes when needed. Additionally, CRE screening informs infection control practices by enabling the cohorting of suspected or confirmed cases, thereby maintaining aseptic conditions. Overall, such studies are crucial for developing targeted infection control policies and preventive strategies.

7. Source of Funding

None.

8. Conflict of Interest

None.

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