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ANTIBIOTIC RESISTANCE PATTERNS OF BLOOD CULTURE ISOLATES IN INTENSIVE CARE UNIT (ICU) PATIENTS: A DESCRIPTIVE CROSS-SECTIONAL STUDY

Original Article (ID: 457)

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ABSTRACT

Background: Bloodstream infections remain a major cause of clinical deterioration and death in intensive care units, where invasive procedures, critical illness, prolonged hospitalization, and extensive antimicrobial exposure increase infection risk. Gram-negative organisms are especially concerning because they frequently acquire resistance to multiple antimicrobial classes, including carbapenems. Local surveillance of causative organisms and susceptibility patterns is therefore essential for selecting appropriate empirical therapy, strengthening infection-prevention practices, and supporting antimicrobial stewardship in critically ill patients overall in practice.

Objective: To determine the blood culture positivity rate, bacteriological profile, antimicrobial resistance patterns, and clinical outcomes among patients admitted to an intensive care unit.

Methods: A retrospective descriptive cross-sectional study analysed 350 eligible ICU patient records with blood cultures obtained for suspected bloodstream infection or sepsis. Demographic, clinical, microbiological, susceptibility, and outcome data were extracted using a structured form. Multidrug resistance, carbapenem resistance, septic shock, mechanical ventilation, ICU stay, and mortality were assessed. Chi-square or Fisher's exact test, Welch's t-test, and Mann–Whitney U test were applied, with $p<0.05$ considered significant.

Results: Blood cultures were positive in 70/350 patients (20.0%), and all isolates were Gram-negative. *Acinetobacter* species accounted for 24/70 isolates (34.3%), *Klebsiella* species for 22/70 (31.4%), and *Pseudomonas* species for 15/70 (21.4%). Multidrug resistance and carbapenem resistance were each present in 58/70 isolates (82.9%). Resistance was 100.0% to ampicillin and ceftriaxone, 96.8% to amoxicillin–clavulanate, 87.5% to ciprofloxacin, 84.6% to cefepime, 82.9% to carbapenems, and 77.6% to piperacillin–tazobactam. Tigecycline susceptibility was 92.6%. Mortality was higher in culture-positive than culture-negative patients (80.0% vs 57.9%; $p=0.001$). Culture positivity was associated with older age, longer ICU stay, septic shock, and mechanical ventilation (all $p\leq0.001$), but not with sex ($p=0.500$).

Conclusion: Gram-negative bloodstream infections showed a high burden of multidrug and carbapenem resistance and were associated with adverse ICU outcomes. Unit-specific antibiograms, prompt culture-guided treatment, antimicrobial stewardship, and strengthened infection-control practices are therefore essential.

Keywords: Bacteremia; Blood Culture; Drug Resistance, Multiple, Bacterial; Gram-Negative Bacterial Infections; Intensive Care Units; Microbial Sensitivity Tests; Mortality

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INTRODUCTION

Bloodstream infections are among the most serious complications encountered in intensive care units because they can progress rapidly to sepsis, septic shock, multiorgan dysfunction, prolonged hospitalization, and death. The risk is particularly high among critically ill patients, who often have impaired host defences, severe underlying illnesses, prolonged hospital exposure, and frequent contact with healthcare environments. In addition, the use of invasive devices, including central venous catheters, urinary catheters, endotracheal tubes, and mechanical ventilation, may disrupt natural protective barriers and provide potential routes for microorganisms to enter the bloodstream. Repeated exposure to broad-spectrum antimicrobial agents further increases susceptibility by altering normal microbial flora and promoting the selection of resistant organisms. Consequently, the timely identification of the causative pathogen and initiation of effective antimicrobial therapy are essential to improving outcomes in patients with suspected bloodstream infection (1,2). Blood culture remains the principal diagnostic method for confirming bloodstream infection. It enables the isolation and identification of the responsible microorganism and provides antimicrobial susceptibility results that can guide targeted treatment. This information is particularly important in the ICU, where clinical signs of infection may be nonspecific and where delays in appropriate therapy can have serious consequences. However, the diagnostic yield of blood culture is influenced by several clinical and procedural factors. Previous antibiotic exposure, inadequate blood volume, improper timing of collection, delays in transportation, contamination during sampling, and variations in the severity or stage of infection may all affect culture positivity. Critically ill patients are frequently started on empirical antibiotics before blood samples are collected, especially when sepsis or septic shock is suspected. Although early treatment may be lifesaving, prior antimicrobial administration can reduce the likelihood of recovering the causative organism and may lead to an underestimation of the actual burden of bloodstream infection (3,4).

Both Gram-positive and Gram-negative bacteria can cause bloodstream infections; however, Gram-negative organisms have become increasingly important in hospital and ICU settings. Organisms such as *Acinetobacter* species, *Klebsiella* species, *Pseudomonas aeruginosa*, and *Escherichia coli* are commonly associated with healthcare-related pneumonia, urinary tract infection, surgical-site infection, wound infection, meningitis, and bloodstream infection. These pathogens are clinically important not only because of their ability to cause severe disease but also because of their tendency to acquire multiple mechanisms of antimicrobial resistance. Their capacity to survive in the hospital environment, colonize vulnerable patients, contaminate equipment, and spread through healthcare contact contributes to their persistence within critical-care units. Infections caused by resistant Gram-negative bacteria are often difficult to treat and may be associated with limited therapeutic options, treatment failure, and poor clinical outcomes (5,6). Antimicrobial resistance has emerged as one of the most important threats to global public health. In 2019, bacterial antimicrobial resistance was estimated to be directly responsible for approximately 1.27 million deaths and associated with nearly 4.95 million deaths worldwide. The development and spread of resistance are driven by several factors, including inappropriate prescribing, unnecessary use of antibiotics, incomplete treatment courses, unrestricted access to antimicrobial agents, and extensive antimicrobial use in human health, agriculture, and animal production. The problem is particularly pronounced in hospitals and ICUs, where critically ill patients commonly receive broad-spectrum antibiotics, multiple antimicrobial combinations, and prolonged courses of treatment. Such exposure creates substantial selective pressure, allowing resistant organisms to survive, multiply, and spread among vulnerable patients (7,8).

Carbapenem resistance among Gram-negative bacteria is of particular concern because carbapenems are commonly reserved for severe infections caused by extended-spectrum beta-lactamase-producing organisms and other multidrug-resistant pathogens. The emergence of carbapenem-resistant *Acinetobacter*, *Klebsiella*, *Pseudomonas*, and related organisms has therefore reduced the effectiveness of some of the most valuable agents available for life-threatening infections. These pathogens have been recognized as high-priority organisms because of their resistance to multiple antimicrobial classes, their potential for hospital transmission, and the limited availability of effective treatment. Infections caused by carbapenem-resistant organisms are associated with prolonged ICU admission, increased treatment costs, greater need for supportive care, and higher mortality. The identification of carbapenemase-producing Enterobacterales is also important because carbapenemase genes may spread between bacterial species and contribute to institutional outbreaks (9,10). The increasing prevalence of multidrug-resistant organisms has made empirical antibiotic selection increasingly difficult. In suspected sepsis, treatment usually needs to be initiated before final culture and susceptibility results become available. Empirical regimens must therefore provide adequate coverage against likely pathogens while avoiding unnecessary exposure to excessively broad-spectrum agents. When local resistance rates are high, commonly recommended empirical antibiotics may be ineffective. Inappropriate initial therapy may permit continued progression of infection, resulting in septic shock, organ failure, prolonged mechanical ventilation, or death. Bloodstream infections among critically ill patients have been associated with mortality rates of approximately 40–60%, although the risk varies according to the infecting organism, severity of illness, resistance pattern, source of infection, and timeliness of treatment. Early administration of an antimicrobial agent that is active against the causative pathogen is therefore a major determinant of survival, particularly in Gram-negative bacteremia (11,12).

At the same time, indiscriminate use of broad-spectrum or reserve antibiotics is not a sustainable solution. Excessive empirical coverage may accelerate resistance, expose patients to adverse drug effects, increase treatment costs, and encourage the emergence of organisms that are resistant to nearly all available therapies. Rational empirical treatment must consequently be based on an understanding of the organisms circulating within a particular healthcare facility and their current susceptibility profiles. Local antibiograms provide valuable evidence for selecting initial antibiotics, revising hospital treatment guidelines, supporting antimicrobial stewardship, and limiting

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unnecessary use of last-resort agents. Such surveillance also helps infection-prevention teams recognize clusters of resistant organisms and strengthen interventions such as hand hygiene, contact precautions, environmental cleaning, device-care bundles, surveillance cultures, isolation procedures, and antibiotic restriction policies. Despite the clinical importance of antimicrobial resistance, the distribution of bloodstream isolates and their resistance patterns varies considerably between countries, hospitals, individual wards, and even different time periods within the same institution. Findings from other regions may therefore not accurately reflect the organisms encountered in a specific ICU. In many resource-constrained healthcare settings, recent unit-specific data regarding blood culture positivity, predominant Gram-negative isolates, multidrug resistance, carbapenem resistance, carbapenemase production, and associated clinical outcomes remain limited. This evidence gap may result in empirical treatment being guided by generalized recommendations rather than by local microbiological patterns.

The present study was therefore designed to answer the research question: what are the distribution and antimicrobial resistance patterns of Gram-negative blood culture isolates among ICU patients, and how are these findings associated with major clinical outcomes? The objective was to determine the blood culture positivity rate, identify the predominant Gram-negative bacterial isolates, assess their antimicrobial susceptibility, multidrug-resistance and carbapenemase-producing profiles, and evaluate their association with mortality, septic shock, mechanical ventilation, and duration of ICU stay. The findings are expected to support evidence-based empirical antibiotic selection, strengthen antimicrobial stewardship, and inform infection-prevention strategies within the ICU.

METHODOLOGY

A descriptive, retrospective cross-sectional study was conducted to determine the bacteriological profile, antimicrobial resistance patterns, and clinical outcomes associated with blood culture findings among patients admitted to the intensive care unit. The study was based on routinely recorded clinical and microbiological data from ICU patients who underwent blood culture testing because of suspected bloodstream infection or sepsis during the study period. The primary outcome was the blood culture positivity rate, while the secondary outcomes included the distribution of bacterial isolates, antimicrobial susceptibility profiles, multidrug resistance, carbapenem resistance, septic shock, requirement for mechanical ventilation, duration of ICU stay, and in-ICU mortality. A total of 350 eligible ICU patient records were selected through non-probability consecutive sampling until the required sample was achieved. Male and female patients of all recorded age groups were eligible when they had been admitted to the ICU, had at least one blood culture obtained during the study period, and had sufficient demographic, clinical, microbiological, and outcome information available for analysis. Records were excluded when the blood culture report or essential clinical outcome data were missing, when the isolate was considered a contaminant rather than a clinically significant pathogen, or when the same culture episode had been entered more than once. Repeated isolation of the same organism from the same patient was counted only once unless the medical record clearly documented a separate episode of infection. Culture-negative patients were retained for estimation of the overall blood culture positivity rate and for comparisons between culture-positive and culture-negative groups. Organism-specific resistance analyses were restricted to clinically significant Gram-negative isolates recovered from positive cultures.

Data were extracted using a structured data collection form developed for the study. The recorded variables included age, sex, comorbid conditions, presumed source of infection, blood culture result, isolated organism, Gram-stain category, antibiotic susceptibility profile, multidrug-resistant organism status, carbapenem-resistant organism status, septic shock, use of mechanical ventilation, length of ICU stay, and final clinical outcome. Each record was reviewed for completeness before entry into the study database. Personal identifiers were excluded from the analytical dataset, access to the collected information was limited to the research team, and the findings were reported in aggregate to maintain patient confidentiality. Blood samples had been collected as part of routine ICU care using an aseptic technique and transported to the microbiology laboratory for processing. Cultures that demonstrated bacterial growth underwent Gram staining, subculture, organism identification, and antimicrobial susceptibility testing. Organisms were identified through standard microbiological procedures based on colony morphology, Gram-stain characteristics, and relevant biochemical reactions. Cultures without detectable bacterial growth after the laboratory's standard incubation period were reported as showing no growth. The Gram-negative organisms evaluated included *Acinetobacter* species, *Klebsiella* species, *Pseudomonas* species, *Proteus* species, *Serratia marcescens*, *Stenotrophomonas maltophilia*, and *Morganella morganii*. All clinically significant isolates, including less frequently recovered organisms, were retained in the descriptive analysis to avoid selective reporting. Ethical approval was obtained from the Institutional Review Board. As the study involved analysis of anonymized clinical records, the requirement for individual informed consent was waived.

Antimicrobial susceptibility testing was performed using the routine standardized method employed by the microbiology laboratory. The antimicrobial agents assessed included ampicillin, amoxicillin-clavulanate, ceftriaxone, ceftazidime, cefepime, piperacillin-tazobactam, meropenem or imipenem, amikacin, gentamicin, ciprofloxacin, tigecycline, and colistin. Susceptibility results were categorized as susceptible, intermediate, or resistant according to the interpretative criteria used by the laboratory. Resistance percentages were calculated using the number of isolates actually tested against each antimicrobial agent as the denominator because every antimicrobial agent was not necessarily tested against every organism. Blood culture positivity was defined as the recovery of a clinically significant bacterial pathogen from at least one blood culture specimen. A multidrug-resistant organism was defined as an isolate that was non-susceptible to at least one antimicrobial agent in three or more antimicrobial classes, based on the available susceptibility profile. A carbapenem-resistant organism was defined as an isolate reported as resistant to meropenem, imipenem, or both. Septic shock

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and mechanical ventilation were identified from the clinical documentation maintained during the ICU admission. ICU mortality was defined as death occurring during the ICU stay, while the duration of ICU stay was calculated from the documented dates of ICU admission and discharge or death.

Data were entered and analysed using a statistical software package. Categorical variables were summarized as frequencies and percentages. Continuous variables were presented as mean with standard deviation when approximately normally distributed and as median with interquartile range when the distribution was skewed. Associations between categorical variables were examined using the chi-square test, while Fisher's exact test was applied when expected cell frequencies were small. Mean values between two independent groups were compared using Welch's independent-samples t-test. Skewed continuous variables, including ICU length of stay, were compared using the Mann–Whitney U test. All statistical tests were two-sided, and a p-value of less than 0.05 was considered statistically significant.

RESULTS

The study included 350 patients who underwent blood culture testing during admission to the intensive care unit. The mean age of the study population was 33.7 ± 13.6 years, while the median age was 31 years, with an interquartile range of 22–45 years. Of the 350 patients, 200 (57.1%) were male and 150 (42.9%) were female. No comorbidity was documented in 255 patients (72.9%). Diabetes mellitus was recorded in 55 patients (15.7%), hypertension in 26 (7.4%), combined diabetes mellitus and hypertension in four (1.1%), and other comorbid conditions in 10 (2.9%). Mechanical ventilation was required in 217 patients (62.0%), while 219 (62.6%) developed septic shock. Overall, 218 patients (62.3%) died during their ICU stay, whereas 132 (37.7%) had a non-fatal outcome. Blood culture growth was detected in 70 of the 350 patients, resulting in a positivity rate of 20.0%. The remaining 280 patients (80.0%) had no bacterial growth. All 70 clinically significant isolates recovered from positive cultures were Gram-negative bacteria. *Acinetobacter* species were the most frequently isolated organisms, accounting for 24 cases (34.3%), followed by *Klebsiella* species in 22 (31.4%) and *Pseudomonas* species in 15 (21.4%). Less frequently isolated organisms included *Proteus* species in five cases (7.1%), *Serratia marcescens* in two (2.9%), *Stenotrophomonas maltophilia* in one (1.4%), and *Morganella morganii* in one (1.4%).

A substantial burden of antimicrobial resistance was identified among the culture-positive isolates. Multidrug resistance was recorded in 58 of the 70 isolates (82.9%), and carbapenem resistance was also recorded in 58 isolates (82.9%). All 24 *Acinetobacter* isolates, all 22 *Klebsiella* isolates, and all five *Proteus* isolates were classified as multidrug-resistant and carbapenem-resistant. Among the 15 *Pseudomonas* isolates, five (33.3%) were multidrug-resistant and six (40.0%) were carbapenem-resistant. Both *Serratia marcescens* isolates were multidrug-resistant, although neither was classified as carbapenem-resistant. The single *Stenotrophomonas maltophilia* isolate was classified as carbapenem-resistant but not multidrug-resistant, while the *Morganella morganii* isolate was classified as neither multidrug-resistant nor carbapenem-resistant. Resistance to commonly used antimicrobial agents was frequent, although the number of isolates tested differed between antibiotics. All isolates tested against ampicillin were resistant (5/5, 100.0%), as were all isolates tested against ceftriaxone (35/35, 100.0%). Resistance was also observed in 30 of 31 isolates tested against amoxicillin-clavulanate (96.8%), 42 of 48 tested against ciprofloxacin (87.5%), 11 of 13 tested against cefepime (84.6%), 58 of 70 tested against meropenem or imipenem (82.9%), and 45 of 58 tested against piperacillin-tazobactam (77.6%). Resistance to gentamicin was recorded in 35 of 56 isolates (62.5%), resistance to amikacin in 41 of 67 (61.2%), and resistance to ceftazidime in 12 of 27 (44.4%).

Tigecycline demonstrated the highest recorded susceptibility, with 50 of 54 tested isolates (92.6%) reported as susceptible and four (7.4%) as intermediate. None of the tested isolates was reported as resistant to tigecycline. Among the 32 isolates tested against colistin, two (6.3%) were reported as susceptible and 30 (93.8%) as intermediate, with no isolate classified as resistant. For carbapenems, 10 of 70 isolates (14.3%) were susceptible, two (2.9%) were intermediate, and 58 (82.9%) were resistant. Mortality was higher among patients with positive blood cultures than among those with no growth. Of the 70 culture-positive patients, 56 (80.0%) died, compared with 162 of the 280 culture-negative patients (57.9%), and this difference was statistically significant ($p = 0.001$). Among culture-positive patients, organism-specific mortality was 15 of 24 for *Acinetobacter* (62.5%), 21 of 22 for *Klebsiella* (95.5%), 13 of 15 for *Pseudomonas* (86.7%), and five of five for *Proteus* (100.0%). Neither patient with *Serratia marcescens* died, whereas the single patients with *Stenotrophomonas maltophilia* and *Morganella morganii* both died. Mortality occurred in 46 of 58 patients with carbapenem-resistant isolates (79.3%) and 10 of 12 patients with non-carbapenem-resistant isolates (83.3%); the difference was not statistically significant ($p = 1.000$).

Septic shock and mechanical ventilation were strongly associated with mortality. Death occurred in 218 of 219 patients with septic shock (99.5%), compared with none of the 131 patients without septic shock ($p < 0.001$). All 217 mechanically ventilated patients died, compared with one of 133 non-ventilated patients (0.8%; $p < 0.001$). Culture-positive patients were older than culture-negative patients, with mean ages of 41.9 ± 10.8 and 31.7 ± 13.4 years, respectively ($p < 0.001$). The median ICU stay was also longer among culture-positive patients at 11 days (interquartile range: 8–13), compared with four days (interquartile range: 2–6) among culture-negative patients ($p < 0.001$). Culture positivity occurred in 56 of 219 patients with septic shock (25.6%) and 14 of 131 patients without septic shock (10.7%; $p = 0.001$). Similarly, 56 of 217 mechanically ventilated patients (25.8%) had positive cultures, compared with 14 of 133 non-ventilated patients (10.5%; $p = 0.001$). Culture positivity did not differ significantly according to sex, occurring in 43 of 200 males (21.5%) and 27 of 150 females (18.0%; $p = 0.500$).

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Table 1. Baseline characteristics and factors associated with blood culture positivity

Variable	Overall (n = 350)	Culture-positive (n = 70; 20.0%)	Culture-negative (n = 280; 80.0%)	p-value
Age, years, mean ± SD	33.7 ± 13.6	41.9 ± 10.8	31.7 ± 13.4	<0.001
Sex, n (%)				0.500
Male	200 (57.1)	43 (61.4)	157 (56.1)	—
Female	150 (42.9)	27 (38.6)	123 (43.9)	—
Comorbidity, n (%)				
No documented comorbidity	255 (72.9)	—	—	—
Diabetes mellitus	55 (15.7)	—	—	—
Hypertension	26 (7.4)	—	—	—
Diabetes mellitus and hypertension	4 (1.1)	—	—	—
Other comorbidity	10 (2.9)	—	—	—
Mechanical ventilation, n (%)	217 (62.0)	56 (80.0)	161 (57.5)	0.001
Septic shock, n (%)	219 (62.6)	56 (80.0)	163 (58.2)	0.001
ICU stay, days, median (IQR)	—	11 (8–13)	4 (2–6)	<0.001
Clinical outcome, n (%)				0.001
Death	218 (62.3)	56 (80.0)	162 (57.9)	—
Non-death outcome	132 (37.7)	14 (20.0)	118 (42.1)	—

Table 2. Distribution, resistance profile, and mortality of Gram-negative blood culture isolates

Organism	Isolates, n (%)	MDR, n (%)	Carbapenem-resistant, n (%)	Death, n (%)
Acinetobacter spp.	24 (34.3)	24 (100.0)	24 (100.0)	15 (62.5)
Klebsiella spp.	22 (31.4)	22 (100.0)	22 (100.0)	21 (95.5)
Pseudomonas spp.	15 (21.4)	5 (33.3)	6 (40.0)	13 (86.7)
Proteus spp.	5 (7.1)	5 (100.0)	5 (100.0)	5 (100.0)
Serratia marcescens	2 (2.9)	2 (100.0)	0 (0.0)	0 (0.0)
Stenotrophomonas maltophilia	1 (1.4)	0 (0.0)	1 (100.0)	1 (100.0)
Morganella morganii	1 (1.4)	0 (0.0)	0 (0.0)	1 (100.0)
Total	**70 (100.0)**	**58 (82.9)**	**58 (82.9)**	**56 (80.0)**

Table 3. Antimicrobial susceptibility profile of Gram-negative blood culture isolates

Antimicrobial agent	Isolates tested, n	Susceptible, n (%)	Intermediate, n (%)	Resistant, n (%)
Ampicillin	5	0 (0.0)	0 (0.0)	5 (100.0)
Amoxicillin–clavulanate	31	1 (3.2)	0 (0.0)	30 (96.8)
Ceftriaxone	35	0 (0.0)	0 (0.0)	35 (100.0)
Ceftazidime	27	13 (48.1)	2 (7.4)	12 (44.4)
Cefepime	13	0 (0.0)	2 (15.4)	11 (84.6)

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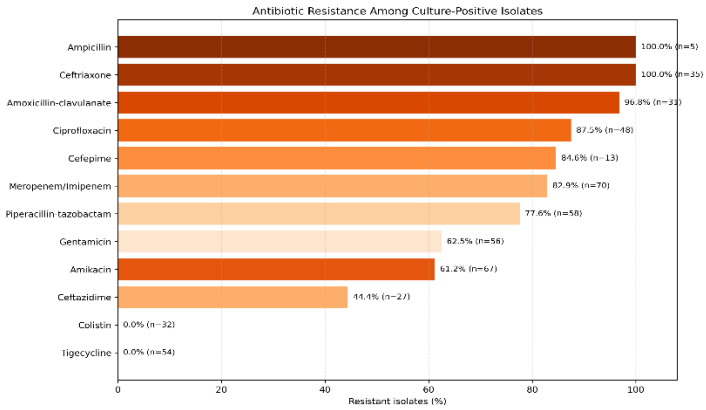
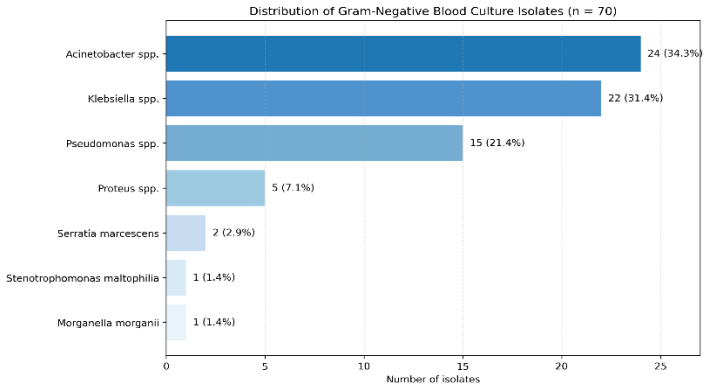
Piperacillin–tazobactam	58	13 (22.4)	0 (0.0)	45 (77.6)
Meropenem/imipenem	70	10 (14.3)	2 (2.9)	58 (82.9)
Amikacin	67	18 (26.9)	8 (11.9)	41 (61.2)
Gentamicin	56	16 (28.6)	5 (8.9)	35 (62.5)
Ciprofloxacin	48	6 (12.5)	0 (0.0)	42 (87.5)
Colistin	32	2 (6.3)	30 (93.8)	0 (0.0)
Tigecycline	54	50 (92.6)	4 (7.4)	0 (0.0)





DISCUSSION

The present study demonstrated that 20.0% of ICU patients who underwent blood culture testing had clinically significant bacterial growth. This finding indicated that bloodstream infection was identified in approximately one in five patients investigated for suspected infection or sepsis. The observed positivity rate was higher than the 10.6% reported in another ICU-based study but lower than the 54.5% reported among patients selected specifically for severe sepsis (11). Such variation was expected because blood culture yield depended on the clinical characteristics of the population, the threshold for requesting cultures, timing and volume of blood collection, prior exposure to antimicrobial therapy, disease severity, and laboratory procedures. Studies restricted to patients with severe sepsis or septic shock would be expected to report higher positivity rates than those including a broader ICU population. Conversely, empirical antibiotic administration before blood sampling may have reduced culture sensitivity and contributed to negative results despite clinically suspected infection. All clinically significant isolates in the present study were Gram-negative bacteria. *Acinetobacter* species were the predominant organisms, followed by *Klebsiella* and *Pseudomonas* species. This distribution was consistent with the established importance of Gram-negative pathogens in healthcare-associated infections, particularly among critically ill patients exposed to invasive devices, prolonged hospitalization, mechanical ventilation, and repeated courses of broad-spectrum antibiotics. Previous ICU studies also identified Gram-negative bacteremia as an important contributor to morbidity and mortality, with *Pseudomonas aeruginosa* and other non-fermenting organisms frequently recovered from critically ill patients. Nevertheless, the complete absence of Gram-positive organisms required cautious interpretation. It may have reflected the local epidemiological pattern, case selection, laboratory reporting practices, exclusion of possible contaminants, or the period during which the data were collected rather than the true absence of Gram-positive bloodstream infections.

The predominance of *Acinetobacter* was clinically important. This organism can survive for prolonged periods on hospital surfaces and equipment and has been associated with ventilator-associated pneumonia, catheter-related infection, environmental contamination, and ICU outbreaks. Its high frequency may have reflected intense antimicrobial pressure and transmission within the critical-care environment. The substantial proportions of *Klebsiella* and *Pseudomonas* further supported the need for strict infection-prevention practices, including hand hygiene, device-care bundles, environmental disinfection, contact precautions, and surveillance of resistant organisms. However, the available data did not establish whether the infections were community-acquired, hospital-acquired, or specifically ICU-acquired. The findings therefore described the microbiological burden among ICU patients without proving that transmission had occurred within the unit. A major finding was the high prevalence of antimicrobial resistance. Multidrug resistance and carbapenem resistance were each recorded in 82.9% of culture-positive isolates. This MDR rate exceeded the 67.9% reported in a previous study from Saudi Arabia, although similarly high resistance had been documented among *Acinetobacter* isolates in other settings (13,14). All *Acinetobacter* and *Klebsiella* isolates in the present study were categorized as both multidrug-resistant and carbapenem-resistant. These results suggested that standard empirical regimens may have provided inadequate coverage for a large

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proportion of Gram-negative bloodstream infections in this ICU. At the same time, resistance rates should not automatically justify unrestricted use of reserve antibiotics, as excessive broad-spectrum therapy may further increase selective pressure and accelerate the emergence of resistance.

The observed burden of carbapenem resistance was substantially higher than the 27.7% reported in another investigation of Gram-negative bloodstream isolates. In that study, *Acinetobacter baumannii* had the highest carbapenem resistance rate at 80.4%, followed by *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* (15,16). Differences between studies may have resulted from variation in local prescribing practices, infection-control performance, patient referral patterns, organism distribution, and laboratory methods. The present findings remained particularly concerning because carbapenems are commonly reserved for severe infections caused by extended-spectrum beta-lactamase-producing and other resistant Gram-negative organisms. Their reduced activity limited treatment options and increased dependence on potentially toxic or less extensively validated alternatives. Resistance was also high against ceftriaxone, ampicillin, amoxicillin-clavulanate, ciprofloxacin, cefepime, piperacillin-tazobactam, aminoglycosides, and carbapenems. Similar reductions in susceptibility to fluoroquinolones, beta-lactam–beta-lactamase inhibitor combinations, and carbapenems have been described in ICU-associated Gram-negative bacteremia (17). These findings supported the development of an ICU-specific antibiogram rather than reliance on hospital-wide susceptibility data. Regular revision of empirical treatment protocols would be necessary because resistance patterns can change rapidly over time and may differ across wards within the same institution.

Tigecycline showed the most favourable susceptibility profile, whereas no isolate was reported as resistant to colistin. These findings required careful interpretation. Tigecycline has pharmacokinetic limitations in bloodstream infection because relatively low serum concentrations may restrict its usefulness as monotherapy for bacteremia. Similarly, the large proportion of colistin results reported as intermediate raised concerns regarding the testing method and interpretative criteria. Colistin susceptibility testing is technically challenging, and results generated by unsuitable methods may be unreliable. Neither agent should therefore be considered universally effective solely on the basis of these percentages. Their use would need to consider the infecting organism, infection source, severity of illness, validated susceptibility testing, toxicity, and antimicrobial stewardship principles. The high resistance burden was consistent with the global importance of antimicrobial resistance, which was estimated to have directly caused 1.27 million deaths and contributed to 4.95 million deaths in 2019 (18). Carbapenem-resistant *Acinetobacter*, Enterobacterales, and *Pseudomonas* have also remained prominent within the WHO bacterial priority pathogen framework. Overall ICU mortality was 62.3%, and mortality was significantly higher among culture-positive than culture-negative patients, at 80.0% and 57.9%, respectively. Culture-positive patients were also older, had longer ICU stays, and more frequently experienced septic shock and mechanical ventilation. These findings indicated that culture positivity occurred in a group with greater clinical severity. Previous studies similarly reported higher rates of organ dysfunction and septic shock among bacteremic patients (19). However, culture positivity itself could not be assumed to have caused the excess mortality. Other studies found comparable mortality between culture-positive and culture-negative septic shock despite greater organ dysfunction among culture-positive patients (20). Mortality was likely influenced by several overlapping factors, including age, baseline illness severity, infection source, organ failure, timing and appropriateness of antimicrobial therapy, resistance profile, and access to supportive care.

Septic shock and mechanical ventilation showed extremely strong associations with mortality. Although these relationships were clinically plausible, the near-complete overlap between these variables and death was unusual and required verification against the original records. Such findings may have reflected a highly selected population, documentation practices, coding errors, or the recording of ventilation and shock late in the clinical course. The absence of severity measures such as APACHE II, SOFA score, lactate level, vasopressor requirement, and organ dysfunction limited adjustment for confounding (12). The study had several strengths, including a relatively large ICU sample, simultaneous evaluation of microbiological and clinical outcomes, assessment of multiple antimicrobial agents, and generation of locally relevant resistance data. Its limitations included the retrospective cross-sectional design, single-centre setting, incomplete information regarding previous antibiotic exposure, infection source, device use, timing of culture collection, and appropriateness of empirical treatment. The small numbers of several organisms limited organism-specific comparisons, and varying susceptibility-testing denominators reduced direct comparison across antibiotics. Molecular characterization of resistance mechanisms and confirmation of carbapenemase production were not performed. Future prospective multicentre studies should incorporate standardized culture methods, validated susceptibility testing, severity scores, antimicrobial-treatment timelines, infection-source classification, molecular resistance testing, and multivariable analysis. Such work would clarify independent predictors of mortality and support more precise empirical treatment and infection-control policies.

CONCLUSION

The study concluded that bloodstream infections among ICU patients were predominantly caused by Gram-negative organisms, with a substantial burden of multidrug and carbapenem resistance. Culture positivity was associated with greater clinical severity, prolonged ICU stay, septic shock, mechanical ventilation, and poorer outcomes. The marked resistance to commonly used antibiotics emphasized the need for regular ICU-specific antibiograms, timely blood culture testing, careful selection of empirical therapy, and prompt adjustment of treatment according to susceptibility results. Strengthening antimicrobial stewardship, infection-control practices, environmental surveillance, and device-care protocols remained essential to limit the spread of resistant pathogens and improve outcomes in critically ill patients.

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