Original Article

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DOI: 10.4103/ijh.ijh_155_25

Etiology, antimicrobial resistance, and outcomes of bloodstream infection in neutropenic hematological patients

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Abstract:

BACKGROUND: Bloodstream infections (BSIs) cause significant morbidity and mortality in neutropenic patients with hematological malignancies, especially amid rising antimicrobial resistance. Updated local data are essential to guide empirical therapy.

OBJECTIVES: The aims of this study were to assessed the etiology, resistance patterns, clinical outcomes of BSIs, and the diagnostic performance of real-time PCR (RT-PCR) versus conventional blood culture.

MATERIALS AND METHODS: A prospective observational study was conducted at Azadi Teaching Hospital (September 2024–May 2025) on 109 neutropenic adults. Blood cultures and multiplex RT-PCR were used to identify pathogens and resistance genes. Clinical features, antimicrobial susceptibility, and 30-day outcomes were analyzed.

RESULTS: BSIs occurred in 24 patients (22%). Blood culture positivity was low (3.7%), while RT-PCR detected pathogens in 20.2%, increasing diagnostic yield nearly sixfold. Gram-negative bacteria predominated (70.8%), mainly *Escherichia coli* (37.5%), and *Klebsiella pneumoniae* (20.8%). ESBL production was universal, and 72.7% of Gram-negative isolates were carbapenem-resistant. Resistance genes included NDM (33.3%), VIM (8.3%), OXA-48 (4.2%), and mecA (12.5%). MDR pathogens caused 54.2% of infections. Appropriate empirical therapy was achieved in 62.5%. Intensive care unit (ICU) admission occurred in 29.1% of BSI cases. Overall mortality was 10.1%, with BSI-related mortality of 29.2%. Carbapenem-resistant infections significantly increased mortality (57.1% vs. 11.1%). Predictors of death included carbapenem resistance, ICU admission, and neutropenia >7 days.

CONCLUSIONS: BSIs in neutropenic hematological patients are mostly caused by MDR Gram-negative organisms with high carbapenem resistance. RT-PCR substantially improves diagnostic sensitivity. Updated empirical therapy and stronger antimicrobial stewardship are urgently needed.

Keywords:

Antimicrobial resistance, bloodstream infection, hematological malignancies, neutropenia

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Submission: 17-11-2025
Revised: 07-01-2026
Accepted: 10-01-2026
Published: 14-03-2026

Introduction

Despite breakthroughs in supportive care and antimicrobial medication, bloodstream infections (BSIs) continue to be the leading cause of morbidity and mortality in neutropenic patients with hematological malignancies. Neutropenia, defined as an absolute neutrophil count (ANC) of <0.5 × 109/L, is a common adverse result of using chemotherapy in hematological malignancies like acute leukemia, lymphoma, and multiple myeloma. The immunological suppression caused by neutropenia predisposes patients to infectious problems, with BSIs being among the most dangerous.[1,2]

The underlying causative microorganisms of blood infections in such patients have

How to cite this article: Najeeb N, Eissa AA, Abdullah BH. Etiology, antimicrobial resistance, and outcomes of bloodstream infection in neutropenic hematological patients. Iraqi J Hematol 2026;15:78-84.

changed over the last several decades. Gram-negative bacteria, such as *Escherichia coli* and *Pseudomonas aeruginosa*, were the most common organisms before 50 years,[3] however, with the introduction of prophylactic antibiotics, indwelling catheters, and mucositis-inducing chemotherapy in the 1990s and early 2000s, there was a change to gram-positive organisms such as coagulase-negative *staphylococci*, *Staphylococcus aureus*, and *Enterococcus* species.[4,5] More recently, there has been a disturbing reemergence of multidrug-resistant (MDR) gram-negative bacilli, such as ESBL-producing *Enterobacteriaceae*, carbapenem-resistant *Klebsiella pneumoniae*, and MDR *Acinetobacter baumannii,* confounding empirical treatment techniques.[6-8]

Antimicrobial resistance (AMR) in BSI pathogens is a growing global problem, particularly in immunocompromised patients. Neutropenic patients frequently get numerous courses of broad-spectrum antibiotics, which provide selection pressure and contribute to the emergence of resistant strains.[9] Inappropriate or delayed beginning of effective antimicrobial medication in these patients is related with inferior outcomes, such as longer hospitalization, greater healthcare expenses, and higher death rates.[10,11] Furthermore, colonization with MDR organisms is increasingly recognized as an independent risk factor for future infection and mortality, particularly in hematology-oncology wards.[12]

The difficulties of handling BSIs in neutropenic individuals are enhanced by the variety of clinical manifestations. Fever is sometimes the sole early indication of infection, and fast worsening can follow in the absence of quick, focused treatment. The empirical use of antipseudomonal Beta-lactams, typically in conjunction with glycopeptides or aminoglycosides, remains the foundation of initial treatment.[13] However, the growing incidence of resistant pathogens necessitates antimicrobial stewardship programs and individualized, risk-based therapy.[14]

The outcome of BSI in neutropenic hematological patients depends on a number of criteria, including the causative organism, the presence of antibiotic resistance, the length and severity of neutropenia, and the timing of appropriate therapy. Gram-negative BSIs, particularly those caused by MDR strains, consistently result in poorer outcomes than gram-positive infections.[15] In addition, fungal BSIs, although less common, carry a particularly high mortality rate and are often associated with prolonged neutropenia and prior antifungal exposure.[16]

Despite advances in supportive treatment, the death rate from BSIs in neutropenic patients can be 20%–40%, especially in locations with limited resources and high resistance rates.[17] Early risk categorization, infection control implementation, routine colonization surveillance, and prompt beginning of effective medication are all strategies for improving outcomes.[18]

Given the changing nature of microbial epidemiology and resistance patterns, ongoing monitoring and updated local data are critical for directing empirical therapy. Understanding the current etiology, antibiotic resistance trends, and clinical consequences of BSIs in neutropenic hematological patients is critical for optimizing therapy methods and lowering mortality.

This study aimed to characterize the etiology, AMR patterns, and clinical outcomes of BSIs in neutropenic patients with hematological malignancies, while assessing the added diagnostic value of real-time PCR (RT-PCR) compared with conventional blood culture.

Materials and Methods

Study design and setting

This was a prospective observational study conducted between September 2024 and May 2025 at the Hematology Unit of Azadi teaching hospital. The study protocol was approved by the institutional ethics review board from the general directorate of health/Duhok (Approval No. 26062024-5-9 on June 26, 2024), and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Patient selection

The study included adult patients (≥18 years) with hematological malignancies who developed febrile neutropenia during hospitalization or chemotherapy. Neutropenia was defined as an ANC $< 0.5 \times 10^9$/L. Fever was defined as a single oral temperature of ≥38.3°C or a sustained temperature ≥38.0°C over one hour. Patients were excluded if they had: non-hematological causes of immunosuppression (e.g., solid organ transplant); Received empirical antibiotics for more than 48 h prior to blood sampling; and/or incomplete clinical or microbiological data.

Blood sample collection and microbiological analysis

Upon the onset of febrile neutropenia, two peripheral venous blood samples were obtained from each patient under aseptic conditions.

Blood culture

Two sets of aerobic and anaerobic blood cultures (10 mL each, 20 ml total) were drawn and inoculated into the BACTEC Plus Aerobic/F and Anaerobic/F culture

vials (Becton Dickinson, Sparks, MD, USA). The vials were incubated in a BACTEC FX automated blood culture system for up to 5 days or until flagged positive. Positive cultures were sub-cultured and identified using conventional biochemical methods or automated systems (e.g., VITEK 2 Compact, bioMérieux, France). Antimicrobial susceptibility testing was performed according to Clinical and Laboratory Standards Institute guidelines.[19]

Real-time PCR for pathogen detection

A separate 2.5 mL of blood was collected in EDTA tubes for molecular diagnosis. DNA extraction was performed using the Bio-Speedy® Nucleic Acid Extraction Kit (Bioeksen R and D Technologies, Istanbul, Turkey) according to the manufacturer's instructions. The extracted DNA was subjected to multiplex RT-PCR using the Sepsis qPCR MX-30T Panel (Bioeksen, Turkey), a CE-IVD-marked diagnostic kit capable of detecting over 30 bacterial, fungal, and AMR genes in whole blood and positive blood culture from individuals suspected of sepsis. PCR amplification and detection were performed on the LightCycler® Dx System. Results were interpreted based on cycle threshold (Ct) values, with Ct < 35 considered positive.

The molecular panel included common sepsis pathogens such as Gram + Bacteria: *S. aureus*, *Staphylococcus* spp., *Enterococcus faecium*, *E. faecalis*, *Streptococcus pneumoniae*, *Streptococcus* spp., and *Listeria monocytogenes*. Gram-Bacteria: *P. aeruginosa*, *K. pneumoniae*, *A. baumannii*, *Haemophilus influenzae*, *Klebsiella oxytoca*, *Pseudomonas* spp., *Enterobacteriaceae*, *Stenotrophomonas maltophilia*, *E. coli*, *Neisseria meningitidis*. Fungi: *Candida glabrata*, *Candida tropicalis*, *Candida krusei*, *Candida albicans*, *Candida parapsilosis*, and Drug Resistance: Carbapenem (OXA 48, KPC, NDM, VIM, IMP), Vancomycin (VanA, VanB), Methicillin (mecA + C).

Data collection

Demographic, clinical, and laboratory data were obtained from patients' medical records, including the following: Underlying hematological diagnosis; duration and severity of neutropenia; antimicrobial prophylaxis and empirical treatment; Source and duration of fever; microbiological findings from culture and RT-PCR; AMR profiles; Intensive care unit (ICU) admission, length of hospital stay, and 30-day all-cause mortality.

Definitions and outcomes

- A BSI is defined as the isolation of a known pathogen from at least one blood culture or detection by PCR. PCR results were interpreted in conjunction with clinical findings before confirming BSI
- MDR organisms are defined according to the European CDC (ECDC) criteria[20]
- The primary objective was the BSI incidence using culture and molecular methods
- Secondary outcomes were pathogen spectrum, antibiotic resistance prevalence, and 30-day death rate
- Concordance: Pathogens found by both culture and RT-PCR were considered concordant
- ICU admission: Was defined as transfer to the ICU due to severe sepsis or clinical deterioration requiring advanced organ support, including hemodynamic instability requiring vasopressors, acute respiratory failure requiring mechanical ventilation, altered mental status with organ dysfunction, multi-organ failure, or the need for continuous invasive monitoring as determined by the treating intensivist.

Statistical analysis

Descriptive statistics for continuous variables were reported as means (± standard deviation) or medians (inter-quartile range [IQR]), while categorical variables were presented as frequencies (%). Categorical variables were compared using Chi-squared or Fisher's exact tests. Continuous variables were compared using the Student's *t*-test or the Mann–Whitney *U* test, if needed. Variables with $P < 0.1$ in univariate analysis were included in multivariate logistic regression. $P < 0.05$ was judged statistically significant. The analyses were carried out using SPSS version 26 (IBM Corp., Armonk, NY, USA).

Results

Patient characteristics

A total of 109 neutropenic patients with hematological malignancies were enrolled between September 2024 and May 2025. The median age was 67.5 years (range 18–93 years), with 65 (59.6%) males and 44 (40.4%) females [Table 1]. The underlying malignancies included: Lymphomas: 68 patients (62.4%); acute leukemias: 16 patients (14.7%) and other hematological malignancies (e.g., myelodysplastic syndrome, multiple myeloma): 25 patients (22.9%). The median duration of neutropenia prior to BSI onset was 3 days (IQR: 2–6), and the median ANC at the time of fever was 0.25×10^9/L. Antimicrobial prophylaxis (mainly fluoroquinolones) was administered in 71 (65.1%) patients. The median hospital stay was 12 days (IQR: 8–20), and ICU admission was required for 18 (16.5%) patients.

Etiology of bloodstream infections

BSI was confirmed in 24 of 109 (22.0%) episodes by either blood culture and/or RT-PCR [Table 2]**:** Positive blood cultures: 4/109 (3.7%); Positive RT-PCR results: 22/109 (20.2%); Concordant results (same pathogen by both methods): 2/109 (1.8%); PCR-only detections: 20/109 (18.4%). This indicates that PCR increased the detection rate but may include non-viable organisms.

Table 1: Baseline demographic and clinical characteristics of neutropenic hematological patients

Parameter	Total (*n*=109)	BSI (+) (*n*=24)	BSI (–) (*n*=85)	*P*
Age (years), median (IQR)	67.5 (18–93)	59.2 (18–75)	71.4 (24–93)	0.018
Male sex, *n* (%)	65 (59.6)	14	51	0.82
Underlying disease: Lymphoma/leukemia/other	68/16/25	14/4/6	54/12/19	0.96
Duration of neutropenia (days), median (IQR)	3 (2–6)	4 (2–7)	2.5 (2–6)	0.041
ANC (×10⁹/L), median	0.25	0.11	0.28	0.009
Prophylaxis use, *n* (%)	71 (65.1)	10	61	0.13
ICU admission, *n* (%)	18 (16.5)	12	6	<0.001

IQR=Interquartile range, BSI=Bloodstream infections, ICU=Intensive care unit, ANC=Absolute neutrophil count

Table 2: Comparison of blood culture and real-time transcription-polymerase chain reaction results

Diagnostic method	Positive (*n*)	Percentage of total	Concordant with other method (*n*)
Blood culture	4	3.7	2
RT-PCR	22	20.2	2
Combined (either)	24	22.0	-

RT-PCR=Real-time transcription-polymerase chain reaction

Distribution of pathogens

Gram-negative bacteria were accountable for the majority of microbiological infections. 17 (70.8%), followed by Gram-positive bacteria: 7 (29.2%), and no fungal pathogens. The predominant species were: *E. coli* (9/24, 37.5%), *K. pneumoniae* (5/24, 20.8%), *P. aeruginosa* (3/24, 12.5%), *S. aureus* (4/24, 16.7%), *E. faecalis* (2/24, 8.3%), and *S. pneumoniae* (1/24, 4.2%) [Table 3].

Polymicrobial infections occurred in 3 patients (12.5%). The most frequent source of infection was catheter-related (29.1%), followed by gastrointestinal (25%), respiratory (12.5%), and unknown (33.4%).

BSIs were mainly caused by Gram-negative bacteria (70.8%), particularly *E. coli* and *K. pneumoniae*, followed by *P. aeruginosa*, while Gram-positive organisms were less frequent (29.2%). Gram-negative infections showed high rates of multidrug and carbapenem resistance and were associated with worse outcomes, including higher ICU admission and significantly increased 30-day mortality. In contrast, Gram-positive infections were fewer and generally associated with better clinical outcomes.

Antimicrobial resistance profiles

Phenotypic resistance (culture-based)

All Gram-negative isolates demonstrated high resistance rates to β-lactams and cephalosporins. ESBL-producing isolates: 100% of *E. coli* and *K. pneumoniae*; Carbapenem resistance: 72.7% of Gram-negative isolates; Fluoroquinolone resistance: 75%; Aminoglycoside susceptibility: retained in 60% (amikacin most effective); No vancomycin resistance detected in Gram-positive isolates.

Genotypic resistance (RT-PCR)

Resistance genes were identified in 16 (72.7%) of the PCR-positive cases. Detected genes included: NDM (n = 8, 33.3%); VIM (n = 2, 8.3%); mecA/C (n = 3, 12.5%); OXA-48 (n = 1, 4.2%).

There was a strong correlation (r = 0.81, P < 0.001) between gene detection and phenotypic resistance. MDR organisms were identified in 13/24 (54.2%), and extensively drug-resistant in 3/24 (12.5%) cases.

Clinical response and outcomes

Empirical antibiotic therapy was appropriate (active against the pathogen later identified) in 62.5% of cases (15/24). Treatment modification due to resistance or failure was required in 9 patients (37.5%) [Table 4]. Clinical response (defervescence within 72 h): 58.3%; Median duration of fever: 4 days (IQR: 2–7); ICU admission among BSI patients: 7/24 (29.1%); Overall 30-day mortality: 11/109 (10.1%); infection-attributable mortality: 7/24 (29.2%) among those with confirmed BSI. Patients infected with carbapenem-resistant Gram-negative pathogens died significantly more often (57.1% vs. 11.1% in nonresistant, P = 0.008).

Multivariate logistic regression identified the following independent predictors of 30-day mortality: Carbapenem-resistant infection (odds ratio [OR] 4.6, 95% confidence interval CI 1.5–13.7, P = 0.005); ICU admission (OR 3.9, 95% CI 1.2–12.8, P = 0.021); Duration of neutropenia >7 days (OR 2.7, 95% CI 1.1–8.9, P = 0.043).

Multidrug resistance (MDR) BSIs are associated with significantly worse survival outcomes [Figure 1], likely reflecting the delay in effective therapy, limited treatment options, and the virulence of resistant strains [Table 5]. MDR was defined according to ECDC standards. MDR infections were linked to longer hospital stays, worse response to empirical treatment, and greater fatality rates.

Discussion

BSIs remain one of the most dangerous complications in neutropenic hematological patients, and their clinical effect remains significant despite advancements in supportive care and antimicrobial therapies. The study's findings highlight numerous important

Table 3: Distribution of isolated pathogens and resistance characteristics

Pathogen	*n* (%)	ESBL	Carbapenem-R	MDR	Resistance gene detected
Escherichia coli	9 (37.5)	+	+	+	*NDM* (5), *VIM* (2)
Klebsiella pneumoniae	5 (20.8)	+	+	+	*NDM* (3), *OXA* (1)
Pseudomonas aeruginosa	3 (12.5)	–	+	+	*VIM* (1)
Staphylococcus aureus	4 (16.7)	–	–	+	*mecA* (3)
Enterococcus faecalis	2 (8.3)	–	–	–	-
Streptococcus pneumoniae	1 (4.2)	–	–	–	-

ESBL=Extended spectrum beta lactamase, MDR=Multi-drug resistance

Table 4: Risk variables for 30-day mortality (multivariate logistic regression)

Variable	OR	95% CI	*P*
Carbapenem-resistant infection	4.6	1.5–13.7	0.005
ICU admission	3.9	1.2–12.8	0.021
Duration of neutropenia>7 days	2.7	1.1–8.9	0.043
Age>65 years	1.4	0.5–4.1	0.32
Appropriate empirical therapy	0.4	0.1–1.3	0.11

CI=Confidence interval, OR=Odds ratio, ICU=Intensive care unit

Table 5: Association between multidrug resistance and clinical outcomes in bloodstream infection patients (*n*=24)

Outcome variable	MDR (*n*=13)	Non-MDR (*n*=11)	*P*
Duration of fever (days), mean±SD	5.2±1.8	3.1±1.2	0.01
Length of hospital stay (days), median (IQR)	21 (14–29)	13 (8–19)	0.02
ICU admission, *n* (%)	7 (53.84)	2 (18.18)	0.072
Appropriate empirical therapy, *n* (%)	4 (30.77)	11 (100)	0.001
30-day mortality, *n* (%)	7 (53.84)	4 (36.36)	0.23

MDR=Multidrug resistance, SD=Standard deviation, IQR=Interquartile range, ICU=Intensive care unit

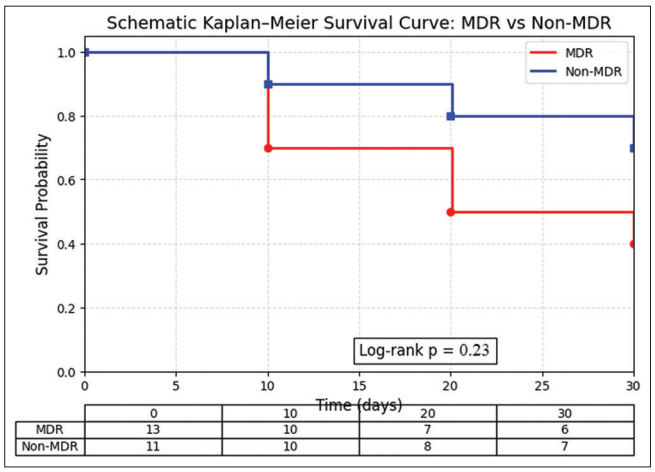

Figure 1: Schematic Kaplan–Meier survival curves comparing patients with multidrug-resistant (MDR) infections versus non-MDR infections. The stepwise curves represent survival probability over 30 days. Circles indicate survival time points for MDR patients, and squares for non-MDR patients. The number of patients at risk at each time point is shown in the table below the x-axis. Survival at day 30 was approximately 46.16% for MDR patients and 63.64% for non-MDR patients. The difference between the groups was assessed using the log-rank test (*P* = 0.23)

epidemiological and clinical characteristics related to BSI causation, diagnostic performance, antibiotic resistance trends, and patient outcomes in a regional Iraqi environment. These findings represent not just local microbial ecology, but also worldwide patterns, providing important insights into neutropenic infection treatment.

The 22% prevalence of BSI in this group is comparable with prior findings from regional and worldwide investigations. The reported incidence of BSI in neutropenic patients varied from 15% to 40%, depending on patient demographics, chemotherapy severity, and diagnostic methods used. For example, similar incidence levels have been recorded in research from North America and Europe,[1,9] and regional data from Iraq reveal comparable infection rates among immunocompromised individuals.[8] This consistency emphasizes the ongoing vulnerability of neutropenic hematological patients to BSIs, regardless of geographic location.

The extremely low blood culture positivity rate (3.7%) likely reflects recognized limitations of conventional cultures in neutropenic patients rather than sampling or laboratory deficiencies. Early initiation of empirical broad-spectrum antibiotics, even for short durations, significantly reduces culture sensitivity, while profound neutropenia is associated with low or transient bacterial loads below culture detection thresholds. In addition, reliance on a single blood culture set may further decrease yield. Similar low culture positivity rates have been reported in neutropenic cohorts, particularly in settings with widespread antimicrobial use. In contrast, RT-PCR detects microbial DNA independent of organism viability, explaining its substantially higher diagnostic yield and supporting its complementary role in febrile neutropenia evaluation.[2,6,21]

The prevalence of Gram-negative bacteria (70.8%) in this study represents an epidemiological change that is becoming more common in many low-income nations with limited resources. Earlier decades saw a shift toward Gram-positive organisms due to prophylactic fluoroquinolone usage and extensive use of indwelling central venous catheters.[5] However, in recent years, Gram-negative organisms have resurfaced as dominating

agents, especially in areas with strong AMR pressure. Gram-negative bacteria predominate in neutropenic oncology units, according to studies from Turkey, Iran, and other Middle Eastern sites.[6,10] The locally observed dominance of *E. coli* and *K. pneumoniae* is consistent with previous findings and most likely reflects broad antibiotic exposure in the population, which contributes to selective pressure for resistant *Enterobacteriaceae*.

Although the multiplex RT-PCR panel included several Candida species, no fungal BSIs were detected in this cohort. This finding may be explained by the relatively short duration of neutropenia in most patients, early initiation of empirical antibacterial therapy, and routine use of antifungal prophylaxis in high-risk hematological patients, which is known to significantly reduce the incidence of candidemia. In addition, invasive fungal infections in neutropenic patients more commonly involve deep-seated tissues (e.g., lung or gastrointestinal tract) rather than bloodstream dissemination, limiting the sensitivity of both culture and blood-based molecular assays. Similar low rates of candidemia have been reported in contemporary hematology cohorts receiving antifungal prophylaxis.[2,9]

The diagnostic comparison of blood culture with RT-PCR demonstrates a considerable advantage for molecular approaches. Culture positivity was very low (3.7%), as would be expected in individuals who had previously received empirical antibiotics or had low bacterial burdens. In comparison, PCR discovered bacteria in 20.2% of cases, representing a roughly sixfold increase. Similar improvements in diagnostic yield were seen in multinational trials testing sepsis molecular panels, where detection rates increased three to tenfold when compared to culture alone.[9] While molecular detection cannot distinguish between live and nonviable bacteria, the capacity to identify infections even after antibiotic commencement is critical in the neutropenic group, where treatment delays considerably decrease outcomes.

The AMR developments in this study are very worrying. ESBL-producing Enterobacterales accounted for more than 75% of Gram-negative isolates, consistent with previously reported data from cancer facilities in Iraq and surrounding regions.[8] More concerning is the rising incidence of carbapenem-resistant pathogens, which impact more than half of Gram-negative isolates. The detection of carbapenemase genes, particularly NDM, which was present in about one-third of cases, is consistent with regional epidemiology, as NDM-producing organisms have been commonly documented throughout the Middle East. International investigations also underline the clinical harm posed by NDM manufacturers, citing limited therapy choices and greater related mortality.[18] The presence of *mecA* in three *S. aureus* isolates emphasizes the MDR load. Although Gram-positive infections were less prevalent in this sample, methicillin resistance remained clinically significant. Similar patterns have been described globally, while MRSA frequency in neutropenic patients varies greatly depending on institution and area infection control strategies.[13]

The clinical effects of MDR and carbapenem-resistant infections were clearly evident in patient outcomes. Patients infected with resistant Gram-negative germs had considerably longer hospital stays, greater ICU admission rates, and significantly higher death rates. The 30-day death rate of 29.2% among BSI patients is comparable with earlier research indicating mortality rates of 20% to 40% in neutropenic cancer patients with bacteremia.[15,17] Furthermore, the 53.8% death rate in carbapenem-resistant illnesses is consistent with the findings of Gedik *et al*.,[10] who found fatality rates above 40% in comparable groups. This underlines that resistance, not infection, determines outcomes.

The independent predictors of mortality – carbapenem-resistant infection, ICU hospitalization, and extended neutropenia – were similarly consistent with previously published worldwide data. Prolonged neutropenia is regarded as a critical driver of severity because it impairs host protection, prolongs bacterial spread, and adds to treatment response delays.[16] Similarly, ICU admission frequently indicates clinical worsening and multi-organ involvement, both of which are related with higher mortality.

The current study's key finding is that empirical treatment is only partially suitable (62.5%). Delays in effective antimicrobial treatment have a considerable impact on mortality in high-risk neutropenic patients.[1] The disparity between empirical regimens and reported resistance profiles implies that local recommendations should be updated and antimicrobial stewardship initiatives strengthened.[14] The high incidence of carbapenemase genes underscores the need for alternate treatment options, such as ceftazidime-avibactam or combination regimens, albeit access to these drugs may be limited in resource-constrained regions.

In summary, the study's findings are consistent with regional and international trends regarding pathogen prevalence, developing antibiotic resistance, and clinical consequences. The prevalence of highly resistant Gram-negative organisms, the diagnostic superiority of PCR, and the high death rate associated with MDR illnesses all highlight the importance of early identification, customized empirical therapy, and stronger infection-control measures. These findings underscore the critical need for ongoing epidemiological

surveillance and stewardship strategies to address the growing hazard of resistant BSIs in neutropenic hematological patients.

Conclusions

Bloodstream infections in neutropenic hematological patients continue to be a significant clinical problem, driven mostly by MDR Gram-negative pathogens, notably ESBL-producing and carbapenem-resistant Enterobacterales. The high incidence of NDM and other carbapenemase genes highlights the vital importance of prompt diagnoses and reevaluation of empirical antibiotic options. Molecular testing indicated considerably more sensitivity than blood culture and should be included in the standard examination of febrile neutropenia. The substantial link between carbapenem resistance, ICU admission, extended neutropenia, and higher mortality emphasizes the critical need for improved antimicrobial stewardship, infection-control procedures, and frequent resistance pattern surveillance. Tailoring empiric treatment based on current local epidemiology is critical for improving outcomes and lowering mortality in this high-risk group.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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