



Original Article

Catheter-Related Bloodstream Infections in Patients Undergoing Hemodialysis through Non-Tunneled Catheters: Incidence, Microbiological Profile, Antimicrobial Susceptibility, and Clinical Outcomes

Dr. Tarkeshwar Kumar¹, Dr. Gulshan Kumar Mukhiya², Dr. Sangita Jaiswal³, Dr. Jyoti Jain⁴, Dr. Tushar Tyagi⁵

¹Assistant Professor, Rohilkhand Medical College & Hospital, Bareilly, U.P, India

²Professor, Department of Nephrology, Geetanjali Medical College & Hospital, Rajasthan, India

³Assistant Professor, Department of OBG, Autonomous State Medical College Kushinagar, U.P, India

⁴Associate Professor, Department of Community Medicine, Geetanjali Medical College and Hospital, Rajasthan, India

⁵Assistant Professor, Venkateshwara Institute of Medical Science, Amroha, U.P, India.

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Corresponding Author:

Dr. Tushar Tyagi

Assistant Professor, Venkateshwara
Institute of Medical Science,
Amroha, U.P, India.

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ABSTRACT

Background: Catheter-related bloodstream infections (CRBSIs) remain one of the most serious complications associated with non-tunneled hemodialysis catheters, leading to increased morbidity, mortality, and healthcare utilization among patients with end-stage kidney disease. Limited Indian data are available regarding their incidence, microbiological profile, and clinical outcomes.

Aim: To evaluate the incidence, microbiological characteristics, antimicrobial susceptibility pattern, and clinical outcomes of CRBSIs in patients with stage V chronic kidney disease (CKD-V) undergoing hemodialysis through non-tunneled catheters.

Materials and Methods: This prospective observational study was conducted in the Departments of Nephrology and Microbiology at Geetanjali Medical College and Hospital, Udaipur, India, between January 2024 and June 2025. Eighty-two adult CKD-V patients with CRBSIs associated with non-tunneled hemodialysis catheters were enrolled. Demographic characteristics, clinical features, laboratory parameters, microbiological findings, antimicrobial susceptibility, and treatment outcomes were recorded. Blood cultures were processed using the BACT/Alert automated system, and antimicrobial susceptibility testing was performed according to Clinical and Laboratory Standards Institute (CLSI) guidelines. Statistical analysis was performed using IBM SPSS version 21.0, with $p < 0.05$ considered statistically significant.

Results: Among 560 patients undergoing non-tunneled catheterization, 82 developed CRBSIs, yielding an incidence of 14.64% and an incidence density of 7.66 episodes per 1,000 catheter-days. Most patients were male (64.6%) and aged < 50 years (59.8%). Fever with chills (69.5%) was the most common presenting feature. Gram-positive cocci (34.2%) were the predominant isolates, with methicillin-resistant *Staphylococcus aureus* (MRSA) accounting for 39.3% of Gram-positive infections, whereas *Escherichia coli* and *Klebsiella* species were the leading Gram-negative pathogens (29.2% each). Vancomycin (89.3%) demonstrated the highest susceptibility among Gram-positive isolates, while colistin/polymyxin (83.3%) and amikacin (75.0%) showed the greatest activity against Gram-negative organisms. Patients with previous CRBSI had significantly higher diastolic blood pressure ($p = 0.009$) and respiratory rate ($p = 0.021$). Following treatment, significant improvements were observed in hemoglobin, serum albumin, total leukocyte count, random blood sugar, alanine aminotransferase, procalcitonin, and C-reactive protein (all $p < 0.001$). Overall survival was 96.3%, with a mortality rate of 3.7%.

Conclusion: Catheter-related bloodstream infections remain a major complication of non-tunneled hemodialysis catheters. Gram-positive organisms, particularly MRSA, predominated, although multidrug-resistant Gram-negative pathogens were also common. Early diagnosis, adherence to catheter-care protocols, and culture-guided antimicrobial therapy are essential to reduce infection-related morbidity and improve clinical outcomes.

Keywords: Chronic kidney disease; Hemodialysis; Non-tunneled catheter; Catheter-related bloodstream infection; Methicillin-resistant *Staphylococcus aureus*; Antimicrobial susceptibility.

INTRODUCTION

Chronic kidney disease (CKD) is a progressive disorder that may advance to end-stage renal disease (ESRD), requiring renal replacement therapy, with hemodialysis (HD) being the most commonly used modality.¹ Although arteriovenous fistulas are the preferred vascular access due to their superior long-term outcomes, central venous catheters (CVCs), particularly non-tunneled catheters, are frequently used when urgent or temporary vascular access is required.^{1,2} However, non-tunneled catheters are associated with a significantly higher risk of catheter-related bloodstream infections (CRBSIs), which are a major cause of morbidity and mortality among HD patients.^{3,4} The risk of CRBSIs is influenced by several patient- and catheter-related factors, including diabetes mellitus, prolonged catheter dwell time, insertion site, and inadequate infection control practices.⁵⁻⁹ These infections often result in sepsis, prolonged hospitalization, interruption of dialysis, and increased healthcare costs.^{10,11} Despite their clinical significance, data regarding the incidence and risk factors of CRBSIs in patients undergoing hemodialysis through non-tunneled catheters in the Indian population remain limited. Therefore, the present study was undertaken to assess the incidence of catheter-related bloodstream infections and identify the associated risk factors among patients undergoing hemodialysis using non-tunneled catheters.

AIM AND OBJECTIVES

The present study aimed to evaluate the incidence, microbiological profile, and clinical outcomes of catheter-related bloodstream infections (CRBSIs) in patients with stage V chronic kidney disease undergoing hemodialysis through non-tunneled catheters. The primary objectives were to determine the incidence of CRBSIs, identify the causative microorganisms and their antimicrobial susceptibility patterns, and assess the clinical outcomes of patients who developed these infections. The secondary objective was to describe the demographic and clinical characteristics of patients who developed CRBSIs associated with non-tunneled hemodialysis catheters.

MATERIALS AND METHODS

This prospective observational study was conducted in the Departments of Nephrology and Microbiology at Geetanjali Medical College and Hospital, Udaipur, Rajasthan, over an 18-month period (January 2024 to June 2025). Adult patients (≥ 18 years) with stage V chronic kidney disease (CKD-V) undergoing hemodialysis through non-tunneled central venous catheters inserted at the study center were consecutively enrolled after obtaining written informed consent. Patients with catheters inserted elsewhere, tunneled catheters, acute kidney injury, active non-catheter-related infections, pediatric patients, and those unwilling to participate were excluded. Based on an expected CRBSI prevalence of 30.7%, 95% confidence level, and 10% allowable error, the calculated sample size was 82 patients.

Catheter-related bloodstream infection (CRBSI) was suspected according to Centers for Disease Control and Prevention (CDC) criteria in patients presenting with fever, chills or rigors, hypotension, or local catheter-site infection. Under aseptic precautions, 10 mL of blood was collected from the catheter venous hub before initiation of antimicrobial therapy for culture and sensitivity testing. Empirical broad-spectrum antibiotics were started and subsequently modified according to culture susceptibility results. Catheters were removed in patients with persistent symptoms or hemodynamic instability despite appropriate antibiotic therapy.

Demographic characteristics, clinical history, comorbidities, laboratory parameters, and microbiological findings were recorded using a structured case record form. Blood cultures were processed using the BACT/Alert automated culture system, organisms were identified by standard microbiological methods, and antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion method according to Clinical and Laboratory Standards Institute (CLSI) guidelines. Patients were followed for two weeks to assess clinical outcomes. The incidence of CRBSI was calculated as the number of CRBSI episodes per total catheter-days $\times 100$. Statistical analysis was performed using IBM SPSS version 21.0. Continuous variables were expressed as mean $\pm$ standard deviation, categorical variables as frequencies and percentages, and comparisons were made using the independent t-test or Chi-square test as appropriate. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 560 patients underwent non-tunneled hemodialysis catheterization during the study period, of whom 82 developed catheter-related bloodstream infections (CRBSIs), resulting in an incidence proportion of **14.64%**. The cumulative catheter exposure was 1,070 catheter-days, with a mean catheter duration of **14.79 ± 8.96 days**(range: 8–33 days), corresponding to an incidence density of **7.66 episodes per 1,000 catheter-days**.

The baseline characteristics of patients with CRBSIs are shown in Table 1. Most patients were aged <50 years (59.8%) and were male (64.6%). Chronic glomerulonephritis (46.3%) was the most common underlying kidney disease, followed by diabetic nephropathy (28.1%) and chronic interstitial nephritis (20.7%). Comorbidities were present in 96.3% of patients, with hypertension (69.6%) and diabetes mellitus (63.3%) being the most frequent. Most patients underwent twice-weekly hemodialysis (86.6%), while catheter insertion was elective in 59.8% and emergency in 40.2% of cases. Right-sided catheter placement was performed in 84.2% of patients, and 13.4% had a previous history of CRBSI.

As shown in Table 2, fever with chills (69.5%) and rigors (62.2%) were the most common clinical manifestations, followed by hypotension (35.4%) and exit-site redness or purulent discharge (18.3%). Shortness of breath (15.9%) and generalized weakness (14.6%) were the most frequent associated symptoms. During follow-up, 41.5% of patients were transitioned to an arteriovenous fistula, whereas 58.5% continued dialysis through catheter access. The overall mortality rate was 3.7%.

The microbiological profile is summarized in Table 3. Gram-positive cocci were the predominant isolates (34.2%), followed by Gram-negative bacilli (29.3%), while non-pathogenic organisms and culture-negative samples each accounted for 18.3%. Among Gram-positive isolates, methicillin-resistant *Staphylococcus aureus* (MRSA) was the commonest pathogen (39.3%), whereas *Escherichia coli* and *Klebsiella* species were the leading Gram-negative organisms (29.2% each).

The antimicrobial susceptibility patterns of CRBSI isolates are presented in Table 4. Among Gram-positive isolates, the highest susceptibility was observed for vancomycin (89.3%), followed by linezolid (71.4%), teicoplanin (67.9%), and gentamicin (67.9%). In contrast, low susceptibility was noted for doxycycline (10.7%), penicillin G (3.6%), azithromycin/erythromycin (3.6%), and daptomycin (3.6%). Among Gram-negative isolates, colistin/polymyxin demonstrated the highest susceptibility (83.3%), followed by amikacin (75.0%) and imipenem/meropenem (66.7%). Lower susceptibility rates were observed for ciprofloxacin (16.7%) and ceftriaxone (4.2%).

Comparison of patients with and without previous CRBSI demonstrated significantly higher diastolic blood pressure (87.91 ± 21.96 vs. 76.86 ± 10.90 mmHg; $p=0.009$) and respiratory rate (22.64 ± 4.78 vs. 19.96 ± 3.28 breaths/min; $p=0.021$) among patients with prior infection. No significant differences were observed for age, body mass index, systolic blood pressure, pulse rate, or body temperature (Table 5).

Changes in laboratory parameters following treatment are presented in Table 6. At two-week follow-up, hemoglobin and serum albumin increased significantly, while total leukocyte count, random blood sugar, alanine aminotransferase, procalcitonin, and C-reactive protein showed significant reductions (all $p<0.001$). No significant changes were observed in aspartate aminotransferase or alkaline phosphatase levels ($p>0.05$).

Table 1. Baseline Characteristics of Patients with Catheter-Related Bloodstream Infections (CRBSIs) (n = 82)

Characteristic	Category	Frequency (n)	Percentage (%)
Age (years)	<50	49	59.76
	≥50	33	40.24
Gender	Male	53	64.63
	Female	29	35.37
Native kidney disease	Chronic glomerulonephritis	38	46.34
	Diabetic nephropathy	23	28.05
	Chronic interstitial nephritis	17	20.73
	Obstructive uropathy	3	3.66
	Autosomal dominant polycystic kidney disease	1	1.22
Presence of comorbidity	Yes	79	96.34
	No	3	3.66
Comorbidities	Hypertension	55	69.62
	Diabetes mellitus	50	63.29
	Hypothyroidism	8	10.13
	Ischemic heart disease	5	6.33

	Chronic liver disease	4	5.06
	Tuberculosis	2	2.53
	Cerebrovascular accident	2	2.53
	Chronic obstructive pulmonary disease	1	1.27
	Hepatitis B	1	1.27
	Hepatitis C	1	1.27
	Malignancy	1	1.27
Hemodialysis frequency	Once weekly	1	1.22
	Twice weekly	71	86.59
	Thrice weekly	10	12.20
Indication for catheter insertion	Elective	49	59.76
	Emergency	33	40.24
Catheter insertion side	Right	69	84.15
	Left	13	15.85
Previous history of CRBSI	Yes	11	13.41
	No	71	86.59

Table 2: Clinical presentation, associated symptoms, and clinical outcomes among patients with CRBSI undergoing hemodialysis through non-tunneled catheters.

Variable		Frequency (n)	Percentage (%)
Clinical presentation	Fever with chills	57	69.51
	Rigors	51	62.19
	Hypotension	29	35.37
	Exit-site redness/purulent discharge	15	18.29
Associated clinical features	Shortness of breath	13	15.85
	Generalized weakness	12	14.63
	Generalized edema	6	7.32
	Loss of appetite	3	3.66
	Cough	3	3.66
	Loose motions	1	1.22
Clinical outcomes	Transition to arteriovenous fistula (AVF)	34	41.46
	Continued catheter use	48	58.54
	Survived	79	96.34
	Death	3	3.66

Table 3: Microbiological Profile of Catheter-Related Bloodstream Infections (CRBSIs) (n = 82)

Microbiological Profile		Frequency (n)	Percentage (%)
Gram-positive isolates (n = 28)	Methicillin-resistant Staphylococcus aureus (MRSA)	11	39.29
	Staphylococcus haemolyticus	8	28.57
	Staphylococcus epidermidis	7	25.00
	Enterococcus faecium	1	3.57
	Enterococcus faecalis	1	3.57
Gram-negative isolates (n = 24)	Escherichia coli	7	29.17
	Klebsiella spp.	7	29.17
	Acinetobacter baumannii	4	16.67
	Ralstonia mannitolilytica	1	4.17
	Pseudomonas aeruginosa	1	4.17
	Raoultella ornithinolytica	1	4.17
	Serratia marcescens	1	4.17
	Enterobacter cloacae	1	4.17
	Burkholderia spp.	1	4.17
Non-pathogenic organisms (n = 15)	Staphylococcus hominis	5	33.33
	Staphylococcus warneri	3	20.00
	Staphylococcus pseudointermedius	3	20.00
	Kocuriakristinae	2	13.33
	Non-pathogenic coagulase-negative Staphylococcus (CONS)	2	13.33

Table 4. Antimicrobial Susceptibility Pattern of CRBSI Isolates

Type of isolates	Antibiotic	Total (Sensitivity%)
Gram-positive isolates (n = 28)	Vancomycin	25 (89.29)
	Linezolid	20 (71.43)
	Teicoplanin	19 (67.86)
	Gentamicin	19 (67.86)
	Rifampicin	14 (50.00)
	Clindamycin	11 (39.29)
	Ciprofloxacin/Ofloxacin	11 (39.29)
	Doxycycline	3 (10.71)
	Penicillin G	1 (3.57)
	Azithromycin/Erythromycin	1 (3.57)
	Daptomycin	1 (3.57)
Gram-negative isolates (n = 24)	Colistin/Polymyxin	20 (83.33)
	Amikacin	18 (75.00)
	Imipenem/Meropenem	16 (66.67)
	Piperacillin/Tazobactam	13 (54.17)
	Ceftazidime	12 (50.00)
	Trimethoprim/Sulfamethoxazole	11 (45.83)
	Cefepime	9 (37.50)
	Cefoperazone/Sulbactam	9 (37.50)
	Ciprofloxacin	4 (16.67)
	Ceftriaxone	1 (4.17)

Table 5: Clinical risk indicators of CRBSI

Clinical risk indicators (Mean $\pm$ SD)	Prior CRBSI (n = 11)	No Prior CRBSI (n = 71)	t value	p-value
Body mass index (kg/m ²)	24.18 $\pm$ 4.85	27.04 $\pm$ 14.78	-0.63	0.528
Age (years)	53.64 $\pm$ 21.09	51.75 $\pm$ 15.83	0.35	0.726
Systolic blood pressure (mmHg)	130.82 $\pm$ 35.91	122.68 $\pm$ 19.50	1.31	0.262
Diastolic blood pressure (mmHg)	87.91 $\pm$ 21.96	76.86 $\pm$ 10.90	2.66	0.009*
Pulse rate (beats/min)	100.55 $\pm$ 15.80	93.41 $\pm$ 15.20	1.44	0.153
Respiratory rate (breaths/min)	22.64 $\pm$ 4.78	19.96 $\pm$ 3.28	2.36	0.021*
Body temperature (°F)	99.09 $\pm$ 1.04	98.80 $\pm$ 0.95	0.92	0.359

Table 6: Comparison of laboratory parameters at the time of diagnosis of CRBSI and at two-week follow-up after treatment in patients undergoing hemodialysis through non-tunneled catheters

Laboratory Parameter (Mean $\pm$ SD)	At Diagnosis of CRBSI	At 2-Week Follow-up	t-value	p-value
Hemoglobin (g/dL)	8.13 $\pm$ 1.65	8.62 $\pm$ 1.96	-4.002	<0.001*
Total leukocyte count ($\times 10^9/L$)	15.04 $\pm$ 5.84	9.71 $\pm$ 2.63	8.441	<0.001*
Random blood sugar (mg/dL)	127.75 $\pm$ 51.73	111.57 $\pm$ 44.70	4.500	<0.001*
Aspartate aminotransferase (U/L)	75.84 $\pm$ 116.89	64.98 $\pm$ 171.90	0.729	0.468
Alanine aminotransferase (U/L)	79.31 $\pm$ 189.56	57.59 $\pm$ 162.55	11.974	<0.001*
Alkaline phosphatase (U/L)	143.36 $\pm$ 72.53	128.34 $\pm$ 70.28	1.932	0.057
Serum albumin (g/dL)	2.45 $\pm$ 0.49	2.72 $\pm$ 0.42	-6.513	<0.001*
Procalcitonin (ng/mL)	43.38 $\pm$ 37.40	9.05 $\pm$ 24.91	8.896	<0.001*
C-reactive protein (mg/L)	100.97 $\pm$ 70.45	16.77 $\pm$ 35.77	11.974	<0.001*

DISCUSSION

The incidence proportion of CRBSI in the present study was **14.64%**, with an incidence density of **7.66 episodes per 1,000 catheter-days**. These findings are consistent with recent reports demonstrating that non-tunneled hemodialysis catheters continue to carry a considerable risk of bloodstream infection despite improvements in infection-control practices. Bitunguramye et al. and Costantine et al. similarly reported a substantial burden of CRBSIs among patients receiving maintenance hemodialysis and emphasized that catheter-dependent dialysis remains an important contributor to infectious

complications, particularly in resource-limited settings.^{12,13} Differences in incidence reported across studies may be explained by variations in catheter type, catheter dwell time, patient characteristics, adherence to aseptic protocols, and institutional infection-prevention measures.²⁻⁴

The demographic characteristics of our study demonstrated that nearly 60% of infected patients were younger than 50 years, while males constituted approximately two-thirds of the study population. Similar male predominance has been reported by Bhojaraja et al., Moin et al., and Agrawal et al., reflecting the greater proportion of male patients undergoing maintenance hemodialysis in many dialysis centers.^{14,15,16} Although advancing age has frequently been associated with increased susceptibility to infections because of immunosenescence and multiple comorbidities, our findings indicate that younger patients with end-stage kidney disease also remain vulnerable to CRBSIs, probably reflecting the demographic profile of patients attending our institution.

Chronic glomerulonephritis was the leading cause of underlying kidney disease, followed by diabetic nephropathy and chronic interstitial nephritis. This differs from several international studies in which diabetic nephropathy predominated among patients with catheter-related infections.^{12, 17} These differences likely reflect regional variations in CKD etiology rather than differences in infection susceptibility.

Almost all patients had one or more associated comorbidities, with hypertension and diabetes mellitus being the most prevalent. Similar observations have been reported by Demirci et al., Weldensae et al., and Matos et al., who identified diabetes and multiple comorbid conditions as important predictors of catheter-related infections because of impaired immune responses, vascular dysfunction, and repeated healthcare exposure.^{18, 19, 20} The coexistence of chronic illnesses further compromises host defense mechanisms and predisposes patients to bloodstream infections.

Most patients underwent twice-weekly hemodialysis, and catheter insertion was performed electively in nearly 60% of cases. Right-sided catheter placement was preferred in the majority of patients, consistent with current vascular access guidelines recommending the right internal jugular vein because of its favorable anatomy and lower complication rates.^{4, 21} Only a small proportion of patients had a previous history of CRBSI; however, these patients require close surveillance because recurrent infections are associated with poorer vascular access outcomes.

Fever with chills and rigors were the most common presenting manifestations, followed by hypotension and exit-site inflammation. Similar findings have been reported by Pasilan et al., Bhojaraja et al., and Jose et al., who identified fever as the predominant clinical manifestation of CRBSI in hemodialysis patients.^{17, 15, 22} The relatively low frequency of exit-site infection observed in the present study supports previous evidence that bloodstream infections frequently occur without obvious local catheter-related signs, emphasizing the importance of maintaining a high index of suspicion whenever systemic symptoms develop during or after dialysis. Among associated manifestations, shortness of breath and generalized weakness were more frequent than gastrointestinal symptoms, reflecting the systemic inflammatory response accompanying bacteremia.

The overall clinical outcome was favorable, with more than 40% of patients successfully transitioned to an arteriovenous fistula and an overall survival of 96.34%. Early diagnosis, prompt initiation of empirical antimicrobial therapy, microbiological confirmation, and timely catheter removal in clinically unstable patients probably contributed to the relatively low mortality observed in our study. Similar observations have been reported by Pandit et al. and Almenara-Tejederas et al., who demonstrated that protocol-based management significantly improves patient outcomes following CRBSI.^{23, 24}

Comparison of patients with and without previous CRBSI demonstrated significantly higher diastolic blood pressure and respiratory rate among patients with recurrent infection, whereas age, body mass index, systolic blood pressure, pulse rate, and body temperature were comparable between the groups. Although previous studies have identified prolonged catheter duration, diabetes, hypoalbuminemia, and previous catheter infections as important predictors of CRBSI,^{13, 18, 20} the higher respiratory rate observed in our cohort may represent an early clinical marker of systemic infection requiring prompt intervention.

The microbiological profile demonstrated that Gram-positive cocci constituted the largest proportion of isolates, followed by Gram-negative bacilli, while culture-negative and non-pathogenic isolates each accounted for approximately one-fifth of cases. These findings are comparable with those reported by Bhojaraja et al., Agrawal et al., Pansuriya et al., and Costantine et al., who also observed predominance of Gram-positive organisms in catheter-related infections because of colonization of the skin surrounding vascular access sites.^{12, 15, 16, 25}

Among Gram-positive pathogens, methicillin-resistant *Staphylococcus aureus* (MRSA) represented the commonest isolate, followed by *Staphylococcus haemolyticus* and *Staphylococcus epidermidis*. Similar observations have been reported by Pasilan et al., Jose et al., and Demirci et al., where *Staphylococcus aureus* and coagulase-negative staphylococci were

identified as the principal pathogens responsible for CRBSIs because of their ability to adhere to catheter surfaces and produce biofilms.^{17, 20, 22} Biofilm formation contributes to persistent infection, antimicrobial resistance, and recurrent bacteremia.

Gram-negative bacilli accounted for nearly one-third of culture-positive infections, with *Escherichia coli* and *Klebsiella* species being the predominant organisms, followed by *Acinetobacter baumannii*. Similar trends have been reported by Moin et al., Bitunguramye et al., and Costantine et al., suggesting an increasing contribution of multidrug-resistant Gram-negative organisms in dialysis-related infections.^{12, 13, 14} Isolation of less common pathogens including *Ralstonia mannitolilytica*, *Raoultella ornithinolytica*, *Burkholderia* species, and *Serratia marcescens* further highlights the diverse microbiological spectrum encountered in patients with repeated healthcare exposure and prolonged catheter dependence.

Culture-negative infections accounted for 18.29% of cases, comparable to previous studies. Possible explanations include prior empirical antibiotic administration, low bacterial inoculum, fastidious organisms, or limitations of conventional microbiological methods.^{16, 17}

The antimicrobial susceptibility profile provides important information for empirical management of CRBSIs. Among Gram-positive isolates, vancomycin demonstrated the highest susceptibility, followed by linezolid, teicoplanin, and gentamicin. Similar findings have been reported by Bhojaraja et al., Jose et al., and Pansuriya et al., supporting the continued effectiveness of glycopeptides against methicillin-resistant staphylococcal infections.^{15, 22, 25} However, poor susceptibility to penicillin, macrolides, and doxycycline reflects the growing burden of antimicrobial resistance among Gram-positive pathogens.

Among Gram-negative isolates, colistin/polymyxin, amikacin, and carbapenems demonstrated the highest susceptibility, whereas resistance was greatest against ceftriaxone and ciprofloxacin. Comparable resistance patterns have been reported by Costantine et al., Moin et al., and Bitunguramye et al., emphasizing the emergence of multidrug-resistant Gram-negative bacteria in dialysis units.^{12, 13, 14} These findings reinforce the importance of institution-specific antibiograms and culture-guided therapy to optimize antimicrobial stewardship and reduce inappropriate antibiotic use.

Serial laboratory evaluation demonstrated significant improvement in several hematological and inflammatory parameters following treatment. Hemoglobin increased significantly after two weeks, although anemia persisted because of the underlying chronic kidney disease. Total leukocyte count, procalcitonin, and C-reactive protein declined markedly, indicating effective resolution of infection. Similar findings have been reported by Bhojaraja et al., Costantine et al., and Demirci et al., who identified these biomarkers as valuable tools for diagnosis and monitoring therapeutic response in CRBSIs.^{12, 15, 20}

Random blood sugar levels also decreased significantly following treatment, probably reflecting resolution of infection-associated stress hyperglycemia. Alanine aminotransferase showed significant improvement, whereas changes in aspartate aminotransferase and alkaline phosphatase were not statistically significant. Serum albumin increased significantly following treatment, although absolute levels remained low. Similar observations have been reported by Bitunguramye et al., Matos et al., and Weldetensae et al., who demonstrated that hypoalbuminemia is an important predictor of infection and adverse outcomes in hemodialysis patients.^{13, 18, 19}

CONCLUSION

Catheter-related bloodstream infections remain a significant complication among patients undergoing hemodialysis through non-tunneled catheters. Gram-positive cocci, particularly methicillin-resistant *Staphylococcus aureus*, were the predominant pathogens, although Gram-negative organisms also contributed substantially to the infectious burden. Early diagnosis, strict adherence to catheter-care protocols, culture-guided antimicrobial therapy, regular surveillance of antimicrobial resistance, and timely transition to permanent vascular access are essential strategies for reducing infection-related morbidity and improving outcomes in this vulnerable patient population.

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