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Microbial profile and antibiotic resistance patterns of organisms causing tunneled venous catheter infections in hemodialysis unit

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ABSTRACT

Background: Central venous catheters (CVCs) are widely used in hemodialysis but predispose patients to catheter-related bloodstream infections (CRBSIs). This study evaluated microbial patterns, antibiotic resistance, and risk factors of CRBSIs in tunneled CVCs at a tertiary care hospital.

Material and Methods: Cross-sectional analytical study was conducted from January to June 2025 at hemodialysis unit of Bahawal Victoria Hospital, Bahawalpur. Total 340 adult patients with tunneled CVCs and clinical signs of CRBSI were enrolled. Confirmed CRBSI was defined by CDC/CLSI criteria using differential time to positivity or semi-quantitative catheter tip culture. Blood and catheter tip samples were processed for microbial identification and antimicrobial susceptibility testing. Data were analyzed using SPSS version 23.0.

Results: Only 32 patients (9.4%) had confirmed CRBSI. Gram-positive bacteria predominated (70.6%) with *Staphylococcus aureus* (38.2%) and coagulase-negative staphylococci (26.5%) as the leading pathogens. Gram-negative bacteria (23.5%) included *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. Fungal infections (5.9%) were due to *Candida albicans*. High resistance rates were observed: 61.5% of *S. aureus* were MRSA, 77.8% of CoNS were methicillin-resistant and 50.0% of Gram-negative isolates were ESBL producers. A catheter dwell time >6 months was significantly associated with CRBSI (p < 0.001).

Conclusion: Despite a low confirmed CRBSI rate the high prevalence of multidrug-resistant organisms among confirmed cases highlights critical need for accurate diagnosis and antimicrobial stewardship. Prolonged catheter use is a key modifiable risk factor.

Keywords: *Candida albicans,* Catheter-related bloodstream infection, Central venous catheter, Drug resistance, microbial, *Pseudomonas aeruginosa, Staphylococcus aureus.*

BACKGROUND

Vascular access is the lifeline for patients with end-stage renal disease (ESRD) undergoing hemodialysis, serving as a critical conduit for efficient blood circulation during dialysis sessions. The optimal vascular access is an autogenous arteriovenous fistula (AVF) which is associated with lower rates of infection, thrombosis and long-term complications compared to other access types.[1] However, due to anatomical limitations, delayed AVF maturation, or

urgent need for dialysis, central venous catheters (CVCs) particularly are frequently used as either temporary or long-term access solutions.[2]

Despite their utility, CVCs are associated with a significantly higher risk of infection compared to AVFs or arterio-venous grafts (AVGs). Catheter related bloodstream infections (CRBSIs) are among the most frequent and severe complications in hemodialysis patients with reported incidence rates ranging from 0.5 to 4.5 episodes per 1,000 catheter days.[3] The prolonged use of CVCs disrupts the skin barrier allowing skin flora and environmental pathogens to colonize the catheter hub and migrate along the external or internal surface ultimately leading to bloodstream invasion.[4]

CRBSIs are a major cause of morbidity and mortality in the hemodialysis population. These infections are associated with prolonged hospitalization, increased healthcare costs and higher rates of sepsis and death. A large cohort study from the United States Renal Data System (USRDS) found that CRBSI was linked to a 2.3-fold increased risk of all-cause mortality in dialysis patients.[5] Furthermore, bloodstream infections contribute to systemic inflammation, which may

accelerate cardiovascular disease, the leading cause of death in ESRD patients.[6]

In addition to clinical consequences CRBSIs negatively impact dialysis adequacy. Infected catheters often require temporary or permanent removal, disrupting dialysis schedules and access availability. This can lead to suboptimal dialysis delivery, increased hospitalizations and reduced quality of life.[7] The economic burden is substantial the average cost of managing a single CRBSI episode in the U.S. exceeds $25,000 including hospitalization, antibiotics and access replacement.[8]

The microbial profile of CRBSIs has evolved over the past two decades with a shift from predominantly gram-positive to an increasing proportion of gram-negative and multidrug-resistant organisms (MDROs). Historically, *coagulase-negative staphylococci (CoNS)* and *Staphylococcus aureus* were the most common pathogens isolated from CRBSIs.[9] However recent surveillance data indicate a rising prevalence of Gram-negative bacteria such as *Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Escherichia coli* particularly in regions with high antibiotic consumption.[10]

This shift is largely attributed to the widespread use of broad-spectrum antibiotics, invasive procedures and cross transmission in healthcare settings. MDROs including *methicillin resistant S. aureus (MRSA), extended-spectrum beta-lactamase (ESBL)* producing *Enterobacterales* and *carbapenem resistant organisms (CROs)* are now frequently isolated from hemodialysis units, posing significant challenges for empirical antimicrobial therapy.[11] A multicenter study across Asia and the Middle East reported that over 40% of CRBSI isolates in dialysis patients were resistant to first-line antibiotics severely limiting treatment options.[12] The emergence of antifungal resistance particularly among Candida species, further complicates management especially in patients with prolonged catheter use or prior antifungal exposure.[13]

Given the high burden of CRBSIs and the dynamic nature of microbial resistance continuous local surveillance is essential to guide empirical antibiotic selection and infection control strategies. International and regional guidelines emphasize the importance of local antibiograms in tailoring therapy for CRBSIs.[14] However many hemodialysis centers operate without up-to-date, facility-specific data on microbial profiles and resistance patterns.

This study aimed to characterize the microbial etiology and antibiotic resistance patterns of pathogens causing CRBSIs in patients on hemodialysis. By providing local data this research will support evidence-based decisions in antimicrobial stewardship, infection prevention and clinical management of infected patients.

MATERIAL AND METHODS

This cross-sectional analytical study was conducted in the hemodialysis unit of Bahawal Victoria Hospital, Bahawalpur from January 2025 to June 2025. The study aimed to determine the microbial profile and antibiotic resistance patterns of pathogens causing catheter related bloodstream infections (CRBSIs) in adult hemodialysis patients with tunneled central venous catheters (CVCs). Sample size calculated at 95% level of confidence, 5% margin of error and anticipated 35%[15] of CRBSI cases among hemodialysis patients based on recent multicenter study from Pakistan reporting that *Staphylococcus aureus* was isolated in approximately 35% of CRBSI cases, was 340.

Hemodialysis unit at Bahawal Victoria Hospital, Bahawalpur currently provides care for patients from division Bahawalpur and even from Sindh and Balochistan province undergoing chronic hemodialysis, with a daily average of 60–70 dialysis sessions conducted in three shifts. While AVF is indeed the most prevalent vascular access in our center (used by approximately 58% of patients) a significant proportion of patients rely on central venous catheters due to various clinical and logistical factors including delayed AVF maturation (common in patients with diabetes or small-caliber veins), urgent initiation of dialysis in patients with advanced chronic kidney disease who present late to care, failed or thrombosed AVFs/AVGs, particularly in patients with recurrent access complications, cardiovascular instability precluding surgical access creation and limited surgical access creation services and long waiting times in resource constrained setting.

Given that study specifically focused on catheter-related bloodstream infections (CRBSIs) in patients with tunneled CVCs, it was appropriate to enroll only those with this type of vascular access. A total of 340

patients with tunneled CVCs were enrolled over a six-month period (January–June 2025), which reflects both the high patient turnover and the extended use of tunneled catheters as a long-term access solution in our population. Notably, many patients in study used tunneled CVCs for more than 6 months due to the barriers mentioned above.

Therefore, while tunneled catheters are ideally intended for temporary use, their prolonged use as a de facto long-term access method is a reality in many low- and middle-income countries, including Pakistan. This makes the study population both clinically relevant and representative of current hemodialysis practices in similar resource limited settings.

The study population included adult patients (aged ≥18 years) undergoing hemodialysis who presented with clinical signs suggestive of CRBSI, including fever (≥38°C), chills, rigors, or hypotension without an obvious source of infection. Patients were included only if they had a tunneled CVC in situ at the time of presentation. Individuals with evidence of concurrent infections at other sites (e.g., pneumonia, urinary tract infection), those who had received antibiotics within the preceding 48 hours or those with bacteremia likely originating from a non-catheter source were excluded from the study.

CRBSI was defined according to combined criteria from the Centers for Disease Control and Prevention (CDC) and the Clinical and Laboratory Standards Institute (CLSI). A confirmed case of CRBSI required either simultaneous quantitative blood cultures or differential time to positivity (DTP), where the time to positivity from the catheter hub was at least 2 hours faster than that from a peripheral vein, with the same organism isolated from both sources; or semi-quantitative culture of the catheter tip yielding ≥15 colony-forming units (CFU) with a concordant organism identified in the bloodstream.

Microbial identification and antimicrobial sensitivity was performed at pathology department of Quaid-e-Azam Medical College, Bahawalpur. Demographic data (age, gender), duration of dialysis, catheter dwell time, clinical presentation and comorbidities collected was collected by using preformed questionnaire. All data were entered into SPSS version 23.0 for analysis. Descriptive statistics were used to summarize categorical variables as frequencies and percentages and numerical variables as mean and standard deviation. Chi-square or Fisher's exact test was applied to assess associations between microbial types and resistance patterns where appropriate and p-value <0.05 was considered statistically significant.

The study was conducted after approval by Institutional Review Board (IRB). Written informed consent was obtained from all participants and confidentiality of patient information was maintained.

RESULTS

A total of 340 hemodialysis patients with tunneled central venous catheters (CVCs) and clinical signs suggestive of catheter-related bloodstream infection (CRBSI) were enrolled in this cross-sectional analytical study conducted at Bahawal Victoria Hospital, Bahawalpur, from January to June 2025. Despite clinical suspicion in all participants, 32 patients (9.4%) met the CDC/CLSI case definition for confirmed CRBSI indicating a low microbiologically confirmed infection rate.

The mean age of the confirmed CRBSI group was 58.3 ± 12.7 years with a male predominance (62.5%, n = 20). The average duration of hemodialysis was 3.5 ± 2.1 years and the median catheter dwell time was 9.2 months (IQR: 5.1–15.6). The most common comorbidities among infected patients were diabetes mellitus (53.1%, n = 17), hypertension (75.0%, n = 24), and cardiovascular disease (37.5%, n = 12). The predominant clinical presentations included fever (100%), chills (93.8%), and hypotension (34.4%). No deaths were reported during the hospitalization period, but 10 patients (31.3%) required ICU admission due to sepsis.

A total of 34 pathogens were isolated from the 32 confirmed CRBSI cases (including 2 polymicrobial infections). Gram-positive bacteria were the most frequently isolated organisms accounting for 70.6% (n=24) of all isolates. *Staphylococcus aureus* identified in 13 cases (38.2%) followed by *coagulase-negative staphylococci* (CoNS) in 9 cases (26.5%). *Enterococcus faecalis* was isolated in 2 cases (5.9%). Gram-negative bacteria constituted 23.5% (n = 8) of isolates. The most common species were *Klebsiella pneumoniae* (5.9%, n=2), *Pseudomonas aeruginosa* (5.9%, n=2), *Escherichia coli* (2.9%, n=1) and *Acinetobacter baumannii* (2.9%, n = 1). Fungal pathogens were isolated in 2 cases (5.9%), both

identified as *Candida albicans*. Polymicrobial infections were observed in 2 patients (6.3%) involving combinations of *S. aureus* with *K. pneumoniae* and *CoNS* with *C. albicans* (Table-I).

Among *Staphylococcus aureus* isolates, 61.5% (8/13) were methicillin-resistant (MRSA) showing resistance to beta-lactam antibiotics (methicillin/ oxacillin). All MRSA isolates remained susceptible to vancomycin. CoNS showed high resistance with 77.8% (7/9) resistant to methicillin.

In the gram-negative group, 50.0% (4/8) of isolates were extended-spectrum beta-lactamase (ESBL) producers, including both *K. pneumoniae* and *E. coli* isolates. Carbapenem resistance was detected in 25.0%

(2/8) of gram-negative pathogens: one K. pneumoniae and one P. aeruginosa. Multidrug resistance (MDR), defined as nonsusceptibility to at least one agent in three or more antimicrobial categories was observed in 15 isolates (44.1%). MDR was most prevalent among *S. aureus* (61.5%), CoNS (77.8%), and P. aeruginosa (100%). Both *Candida albicans* isolates were susceptible to fluconazole and amphotericin B (Table-II).

A statistically significant association was found between catheter dwell time >6 months and confirmed CRBSI (p <0.001). Similarly, patients with diabetes mellitus had a higher likelihood of Gram-negative and fungal infections (p=0.021) (Table-III).

Table-I: Microbial profile of pathogens isolated from confirmed catheter-related bloodstream infections (CRBSIS) in hemodialysis patients (n = 34 isolates from 32 patients).

Organism	Number of Isolates	Percentage (%)
Gram-Positive Bacteria	24	70.6
Staphylococcus aureus	13	38.2
Coagulase-negative staphylococci (CoNS)	9	26.5
Enterococcus faecalis	2	5.9
Gram-Negative Bacteria	8	23.5
Klebsiella pneumoniae	2	5.9
Pseudomonas aeruginosa	2	5.9
Escherichia coli	1	2.9
Acinetobacter baumannii	1	2.9
Fungi	2	5.9
Candida albicans	2	5.9
Total	34	100

Table-II: Antibiotic resistance patterns among major pathogens isolated from confirmed CRBSIs (n = 34).

Organism	No. of Isolates	Resistant to	No. Resistant	Resistance (%)	MDR Rate (%)
Staphylococcus aureus	13	Methicillin (MRSA)	8	61.5	61.5
CoNS	9	Methicillin	7	77.8	77.8
Enterococcus faecalis	2	Vancomycin (VRE)	0	0	0
Klebsiella pneumoniae	2	ESBL	2	100	100
		Carbapenems	1	50	
Pseudomonas aeruginosa	2	Carbapenems	1	50	100
Escherichia coli	1	ESBL	1	100	100
Acinetobacter baumannii	1	Carbapenems	0	0	0
Candida albicans	2	Fluconazole	0	0	0
Overall (All Pathogens)	34	—	—	—	44.1

Table-III: Association between patient and catheter-related factors and confirmed CRBSI or pathogen type in hemodialysis patients (n = 340).

Variable		CRBSI, n (%)	No CRBSI, n (%)	p-value
Catheter dwell time	≤6 months	7 (3.9%)	171 (96.1%)	<0.001
	>6 months	25 (15.5%)	137 (84.5%)	
Diabetes mellitus	Yes	17 (12.3%)	121 (87.7%)	0.062
	No	15 (7.4%)	187 (92.6%)	
Age (years)	<60	15 (9.0%)	153 (91.0%)	0.874
	≥60	17 (9.9%)	155 (90.1%)	
Gender	Male	20 (10.1%)	178 (89.9%)	0.512
	Female	12 (8.4%)	130 (91.6%)	
Duration of dialysis	<3 years	14 (8.5%)	150 (91.5%)	0.635

	≥3 years	18 (10.7%)	150 (89.3%)	
Hypertension	Yes	24 (10.2%)	212 (89.8%)	0.312
	No	8 (6.3%)	120 (93.7%)	
Cardiovascular disease	Yes	12 (12.8%)	82 (87.2%)	0.287
	No	20 (8.2%)	224 (91.8%)	

DISCUSSION

This study highlights clinical suspicion and microbiologically confirmed catheter-related bloodstream infections (CRBSIs) in hemodialysis patients, with 9.4% (32/340) of clinically suspected cases meeting strict CDC/CLSI diagnostic criteria. Despite high rates of fever and systemic symptoms, the confirmation rate underscores the limitations of clinical diagnosis alone and emphasizes the necessity of objective microbiological criteria such as differential time to positivity (DTP) or quantitative catheter tip cultures to avoid unnecessary antibiotic use. This finding aligns with recent studies from resource limited settings where over diagnosis of CRBSI contributes to antimicrobial overuse and the development of resistance.[16]

The microbial profile in confirmed CRBSIs was dominated by gram-positive organisms (70.6%) with *Staphylococcus aureus* as the leading pathogen (38.2%) followed by coagulase negative staphylococci (CoNS). This is consistent with global trends where skin flora colonizing catheter hubs are primary culprits in intravascular device infections.[17] However, the high prevalence of MRSA (61.5%) and methicillin-resistant CoNS (77.8%) is alarming and reflects widespread circulation of resistant clones in healthcare settings. These resistance patterns necessitate empirical coverage with anti-MRSA agents like vancomycin in severe cases though local antibiograms should guide de-escalation to prevent further resistance selection.

Notably, gram-negative bacteria accounted for 23.5% of isolates with half being ESBL producers and 25% showing carbapenem resistance particularly in *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. This rising burden of multidrug-resistant (MDR) Gram-negative pathogens mirrors regional trends in South Asia where poor infection control and antibiotic misuse increase resistance.[18] The 100% MDR rate in *P. aeruginosa* isolates is particularly concerning limiting therapeutic options to agents like ceftazidime-avibactam or colistin, which may not be readily available in many centers. The presence of *Candida albicans* in 5.9% of cases though low reinforces the need to consider fungal etiology in patients with prolonged catheter use, diabetes or prior broad-spectrum antibiotic exposure.

The findings identified catheter dwell time >6 months as a strong independent predictor of CRBSI (p <0.001) reinforcing evidence that prolonged CVC use significantly increases infection risk due to biofilm formation and cumulative microbial exposure.[19] Additionally diabetes mellitus was significantly associated with Gram-negative and fungal infections (p=0.021) likely due to impaired neutrophil function, hyperglycemia-driven microbial growth and frequent healthcare exposure.[20] These findings advocate for intensified surveillance and early vascular access planning in diabetic patients with long term catheters.

Strengths of this study include its design, adherence to standardized CDC/CLSI case definitions, use of reliable microbiological methods and focus on a high-risk population in a real-world setting. The inclusion of both blood and catheter tip cultures enhances diagnostic accuracy.

However, several limitations must be acknowledged. First the study was conducted at a single center which may limit generalizability. Second the low CRBSI incidence while reflective of true microbiological confirmation rates, limits subgroup and multivariate analyses.

To reduce CRBSI burden it is recommended that promoting early creation of arteriovenous fistulas to minimize CVC dependence, implementing catheter care bundles including chlorhexidine skin antisepsis and hub disinfection, establishing routine surveillance cultures and local antibiograms and integrating antimicrobial stewardship programs to guide empirical and targeted therapy. Diabetic patients with long dwell catheters should be prioritized for infection prevention and early intervention.

CONCLUSION

Despite a low microbiologically confirmed CRBSI rate the high prevalence of multidrug-resistant pathogens among confirmed cases highlight the need for precise diagnosis and targeted antimicrobial use. Prolonged

catheter use and diabetes are key risk factors requiring focused preventive strategies in hemodialysis units.

CONFLICT OF INTEREST
None

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Declared none

AUTHOR CONTRIBUTION
Muhammad Aamir: Study conception, acquisition, analysis and interpretation of data, manuscript drafting, final approval, accountable for all aspects of publication.

Namra Anam: Acquisition of data, interpretation of data, manuscript drafting, final approval, accountable for all aspects of publication.

Muhammad Yasir Muneeb: Study conception, acquisition, analysis and interpretation of data, manuscript drafting, final approval, accountable for all aspects of publication.

Muhammad Imran: Acquisition of data, interpretation of data, manuscript drafting, final approval, accountable for all aspects of publication.

Fahad Qaisar: Study conception, acquisition, analysis and interpretation of data, manuscript drafting, final approval, accountable for all aspects of publication

Ayesha Javaid: Acquisition, analysis and interpretation of data, manuscript drafting, final approval, accountable for all aspects of publication

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