Catheter-related Bloodstream Infections Outcomes among Hemodialysis Patients: A Retrospective Cohort Analysis

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ABSTRACT **Background:** Tunneled hemodialysis catheters are frequently used and are a major source of catheter-related bloodstream infections (CRBSI), which result in significant morbidity.

Objectives: To examine the adverse outcomes associated with CRBSIs, including hospitalization, recurrence, 1-year mortality, and catheter outcomes in a hemodialysis setting that uses modern preventive catheter-care practices.

Methods: We conducted a retrospective cohort study of adults with jugular tunneled hemodialysis catheters who met criteria for CRBSI from 1 January 2015 to 31 December 2020 at a tertiary referral center.

Results: Of 380 hemodialysis patients, 75 experienced CRBSI events. The average rate was 1.55 CRBSIs per 100 patient months. The median time from catheter insertion to CRBSI was 179 days; and 68% required inpatient management. Gram-positive bacteria accounted for 53% of isolates, with Gram-negative organisms also being common. Recurrence occurred in 16% of cases and was independently associated with ferritin levels over 500 ng/ml (P = 0.02), albumin levels below 3.5 g/dl (P = 0.011), and uric acid levels under 2.5 mg/dl (P = 0.04). Catheters were removed in 61.3%, exchanged over a guidewire in 24%, and salvaged in 18.6%. The 1-year mortality rate was 28% and was associated with lower weight, catheter salvage, neutrophilia, hypoalbuminemia, and hypokalemia. Using chlorhexidine exit-site dressings was associated with fewer hospital admissions.

Conclusions: Among hemodialysis patients with CRBSI, recurrence and mortality might be linked to a patient's nutritional and inflammatory status. Current preventive measures might reduce hospitalization rates, but in this cohort, they were not associated with lower recurrence or mortality rate.

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KEY WORDS: bloodstream infection, hemodialysis, hospitalization, mortality, recurrence

Tunneled hemodialysis catheters are commonly used, especially among older patients with severe co-morbidities or limited options for permanent vascular access. Catheter dependence is associated with higher rates of bloodstream infections compared to arteriovenous access and leads to frequent hospitalizations, increased healthcare costs, and higher mortality [1-6]. According to the 2014 U.S. National Healthcare Safety Network Dialysis Event Surveillance, the average rate of bloodstream infections in patients with catheters was 2.16 per 100 patient-months [2] and is associated with a high rate of complications and mortality [7].

Over the past two decades, infection-control bundles and catheter-care strategies, such as thorough hub disinfection, exit-site procedures, and antimicrobial or non-antibiotic locks, have been used to reduce the incidence of catheter-related bloodstream infections (CRBSI) and their complications [8-12]. However, factors related to CRBSI outcomes (hospitalization, recurrence, catheter management, and mortality) have been less frequently described than risk factors for CRBSI occurrence [4-6]. Identifying modifiable predictors of poor outcomes can help focus resources and prevention efforts on high-risk patients.

PATIENTS AND METHODS

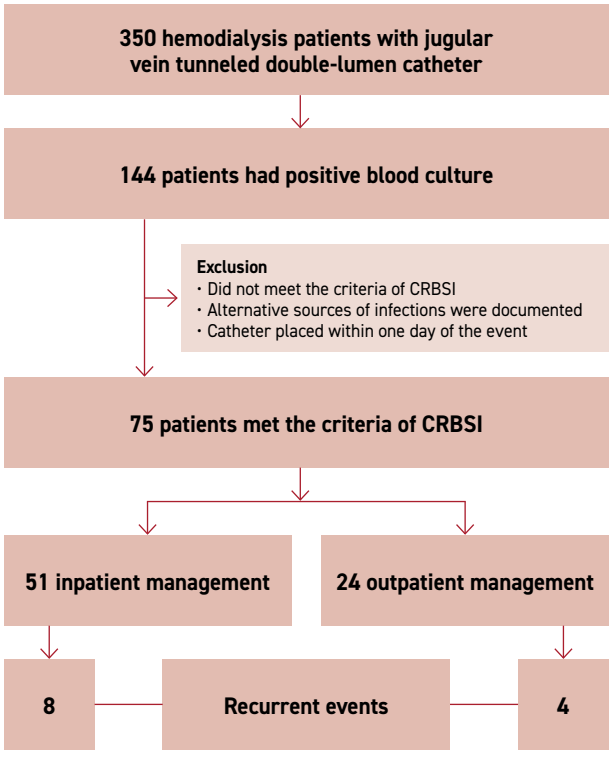
STUDY DESIGN AND SETTING

We conducted a retrospective cohort study involving adult (≥ 18 years) patients on chronic in-center hemodialysis at a tertiary referral hospital who developed tunneled jugular CRBSI between 1 January 2015 and 31 December 2020. The institutional review board approved the study and waived informed consent due to its retrospective design.

Definition of CRBSI: CRBSI events were identified from unit-specific dialysis infection databases and then confirmed by manual review of the verified information in electronic medical records, microbiology results, dialysis documentation, and available clinical notes using U.S. Centers for Disease Control and Prevention criteria. These criteria include a laboratory-confirmed bloodstream infection not attributable to another source, accompanied by clinical signs such as fever, chills, or hypotension. For common commensals (e.g., coagulase-negative staphylococci), at least two positive blood cultures obtained from separate draws were required [13,14] [Figure 1].

Figure 1. Flow diagram of the cohort

Catheter-dependent hemodialysis patients during 2015–2020 and those meeting CRBSI criteria (75 patients); 51 of 75 required inpatient management, while 24 required outpatient management. Recurrent CRBSI episodes occurred in 8 of the inpatient group and 4 of the outpatient group.



DATA COLLECTION

We collected data on demographics, co-morbidities, hemodialysis parameters, and catheter care practices, including exit-site dressing type and lock solutions. Laboratory parameters were obtained from routine blood tests performed within 3 months before the CRBSI episode. Variables specific to CRBSI included the duration since catheter insertion, clinical presentation, microbiology results, empirical and targeted antibiotics, and catheter management.

CATHETER CARE AND TREATMENT PROTOCOLS

The unit adhered to the standard scrub the hub protocol and sterile catheter care procedures. During the study period, chlorhexidine gluconate (CHG) exit-site dressings and taurolidine-based locks were routinely used. Empirical antimicrobial therapy for suspected CRBSI usually includes vancomycin or cefazolin, with coverage for Gram-negative bacteria (e.g., ceftazidime or gentamicin), adjusted based on culture results and susceptibilities [14]. Immediate catheter removal was recommended in cases of persistent instability, severe sepsis despite therapy, metastatic infection, exit-site infection, or bacteremia caused by *Staphylococcus aureus*, candida, pseudomonas, or other multidrug-resistant organisms [14-16].

OUTCOMES

Outcome included hospitalization due to CRBSI, recurrent CRBSI, catheter outcomes (such as removal, guidewire exchange, or salvage), and all-cause mortality within one year.

STATISTICAL ANALYSIS

Categorical variables are reported as frequencies and percentages. Continuous variables are presented as mean ± SD or median (interquartile range [IQR]), as appropriate. Group comparisons utilized chi-square or Fisher's exact tests for categorical data and *t*-tests or Mann–Whitney tests for continuous data. Time-to-death was analyzed using the Kaplan–Meier method and compared with the log-rank test. Multivariable regression models were carefully constructed due to the limited number of outcome events. Candidate variables were selected based on clinical relevance and univariable associations, while avoiding model overfitting. Therefore, multivariable analyses should be viewed as exploratory. *P*-values < 0.05 were considered statistically significant.

RESULTS

Over the 5-year study period, 380 patients received hemodialysis using tunneled jugular catheters. Among them, 75 patients (20%) experienced at least one CRBSI. The overall CRBSI rate was 1.55 per 100 patient-months.

Table 1 presents the baseline characteristics of the study population. The most common co-morbidities were hypertension and diabetes mellitus, affecting 94.6% and 70.6% of patients, respectively, while malignancy was present in 24% of individuals.

Table 1. Baseline characteristics of 75 patients with CRBSI

Characteristic	Value
Age (years), mean ± SD	68 ± 11.6
Female, n (%)	48 (64%)
Weight (kg), mean ± SD	76.5 ± 15
Diabetes mellitus, n (%)	53 (70.6%)
Hypertension, n (%)	71 (94.6%)
Ischemic heart disease, n (%)	37 (49.3%)
LVEF < 40%, n (%)	14 (18%)
Pulmonary hypertension, n (%)	31 (41.3%)
Peripheral vascular disease, n (%)	32 (42.6%)
Malignancy, n (%)	18 (24%)
Immunosuppression drugs, n (%)	5 (6.6%)
Steroids, n (%)	27 (36%)
Catheter indwelling to CRBSI, median (IQR)	179 (3–1628)
Dialysis blood flow (ml/min), mean ± SD	264 ± 22
IDWG (kg), mean	1.7 ± 0.8
Kt/V, mean ± SD	1.2 ± 0.2
CHG dressing, n (%)	22 (29.3%)
Urokinase use, n (%)	15 (20%)
Catheter lock	
Heparin, n (%)	23 (30.6%)
Taurolidine, n (%)	21 (28%)
Citrate 4%, n (%)	31 (41.3%)
Anticoagulation	
Heparin, n (%)	54 (72%)
Enoxaparin, n (%)	2 (2.6%)
Fondaparinux, n (%)	1 (1.3%)

CHG = chlorhexidine gluconate, CRBSI = catheter-related bloodstream infection, IDWG = inter dialytic weight gain, KT/V = dimensionless ratio representing dialysis adequacy, LVEF = left ventricle ejection fraction, IQR = interquartile range, SD = standard deviation

Table 2 presents details on the characteristics of CRBSIs. The median time from catheter insertion to CRBSI was 179 days (IQR 3–1628 days), and 89% of episodes were symptomatic. In addition, early CRBSIs occurring within 3 months of catheter insertion were observed in 23 patients (30.6%). Gram-positive organisms accounted for 53% of isolates, including coagulase-negative staphylococci (26.6%), *S. aureus* (14.6%), and enterococci (8%). Gram-negative organisms were also common, such as pseudomonas (24%). Resistant pathogens were identified in 37.3% of cases (methicillin-resistant *S. aureus* 25%, extended-spectrum beta-lactamase-producing organisms 12%). Empirical antimicrobial therapy was appropriately used without modification in 69% of cases.

Table 2. Catheter-related bloodstream infection characteristics

Characteristic	Value
Symptoms	67 (89%)
Fever, n (%)	22 (29%)
Chills, n (%)	45 (60%)
Weakness, n (%)	15 (20%)
Septic shock, n (%)	4 (5.3%)
Exit-site infection, n (%)	5 (6.6%)
Empiric treatment	
Empiric gentamycin, n (%)	25 (33.3%)
Empiric ceftazidime, n (%)	52 (69.3%)
Empiric cefazolin, n (%)	19 (25.3%)
Empiric vancomycin, n (%)	44 (58.6%)
Bacterial profile	
CONS, n (%)	20 (26.6%)
Staphylococcus aureus, n (%)	11 (14.6%)
Enterococcus faecalis, n (%)	6 (8%)
Streptococcus spp., n (%)	2 (2.6%)
Pseudomonas, n (%)	18 (24%)
Enterobacter cloacae, n (%)	7 (9.3%)
Escherichia coli, n (%)	4 (5.3%)
Proteus mirabilis, n (%)	4 (5.3%)
Klebsiella pneumonia, n (%)	4 (5.3%)
Serratia marcescens, n (%)	2 (2.6%)
Citrobacter freundii, n (%)	1 (1.3%)
Acinetobacter sp. n (%)	1 (1.3%)
Resistance pathogens, n (%)	28 (37.3%)
MRSA, n (%)	19 (25.3%)
ESBL, n (%)	9 (12%)

CONS = coagulase-negative staphylococci, ESBL = extended-spectrum beta-lactamase; MRSA = methicillin-resistant *Staphylococcus aureus*

OUTCOMES

Hospitalization

Fifty-one patients (68%) required hospitalization [Table 3]. Their baseline characteristics and bacterial pro-

Table 3. Characteristics of inpatient and outpatient CRBSI management

Variable	Inpatient management (n=51)	Outpatient management (n=24)	*P*-value
Age (mean, years)	68.4 ± 11.4	68 ± 13	0.98
Female, n (%)	31 (60.7%)	17 (70.8%)	0.39
Weight (kg), mean	75 ± 14.9	79.8 ± 16.5	0.24
Diabetes mellitus, n (%)	37 (72.5%)	16 (66.6%	0.60
Hypertension, n (%)	47 (92%)	24 (100%)	0.29
Ischemic heart disease, n (%)	26 (50.9%)	11 (45.8%)	0.67
Malignancy, n (%)	7 (13.7%	3 (12.5%)	1.00
Immunosuppressive drugs, n (%)	5 (9.8%)	0 (0.0%)	0.17
Catheter indwelling to CRBSI, median (IQR)	179 (6–1628)	185 (2–1149)	0.67
Symptomatic episode, n (%)	45 (88.2%)	22 (91.6%)	1.00
Fever, n (%)	16 (31.3%)	6 (25.0%)	0.57
Chills, n (%)	28 (54.9%)	13 (54.1%)	0.95
Septic shock, n (%)	2 (3.9%)	0 (0%)	1.00
Bacterial profile			
CONS, n (%)	14 (27.4%)	6 (25.0%)	0.82
Staphylococcus aureus, n (%)	9 (17.6%)	2 (8.3%)	0.48
Pseudomonas, n (%)	10 (19.6%)	8 (33.3%)	0.19
MRSA, n (%)	14 (27.4%)	5 (20.8%)	0.53
ESBL, n (%)	6 (11.7%)	3 (12.5%)	1.00
Catheter locks			
Heparin, n (%)	15 (29.4%)	7 (29.1%)	0.43
Taurolock, n (%)	12 (23.5%)	9 (37.5%)	0.36
Citric acid 4%, n (%)	23 (45%)	8 (33.3%)	0.22
CHG dressing, n (%)	11 (21.5%)	11 (45.8%)	0.03
Empiric vancomycin, n (%)	36 (70.5%)	8 (33.3%)	0.001
Empiric cefazolin, n (%)	10 (19.6%)	9 (37.5%)	0.09
Empiric ceftazidime, n (%)	10 (19.6%)	9 (37.5%)	0.09
Empiric gentamycin, n (%)	18 (35.2%)	7 (29.1%)	0.59
Catheter extraction, n (%)	36 (70.5%)	10 (41.6%)	0.05
Laboratory characteristics			
Kt/V, mean ± SD	1.3 ± 0.2	1.1 ± 0.2	0.06
HGB (g/dl), mean ± SD	10 ± 1.3	10.4 ± 1.8	0.44
WBC (K/microL), mean ± SD	8 ± 2.1	7.6 ± 3.5	0.14
Neutrophils (K/microL) mean ± SD	68 ± 15.6	72.1 ± 9	0.40
Albumin (g/dl), mean ± SD	3.2 ± 0.4	3.3 ± 0.4	0.68
Potassium (meq/l), mean ± SD	5 ± 0.8	5.3 ± 0.6	0.22
Uric acid (mg/dl), mean ± SD	6.5 ± 1.6	6.4 ± 1.8	0.61
CRP (mg/l), median (IQR)	18.5 (0.3–103)	28.3 (0.15–167)	0.56
Ferritin (ng/ml), median (IQR)	488 (37–2380)	389 (23–2235)	0.24
PTH (pg/ml), median (IQR)	438.5 (6.4–2500)	537 (15–2500)	0.59

CHG = chlorhexidine gluconate, CRBSI = catheter-related bloodstream infection, CONS = coagulase-negative Staphylococci, CRP = C-reactive protein, ESBL = extended spectrum beta-lactamase, HGB = hemoglobin, KT/V = a dimensionless ratio representing dialysis adequacy, MRSA = methicillin-resistant *Staphylococcus aureus*, PTH = parathyroid hormone, WBC = white blood cells, IQR = interquartile range, SD = standard deviation

files were similar to those of outpatients. However, empiric vancomycin use in hospitalized patients was significantly higher than in those managed as outpatients ($P < 0.001$).

Patients with recurrent CRBSI had a higher hospitalization rate than those with only one episode (83% vs. 68%, $P = 0.01$). Use of CHG exit-site dressings was associated with a lower hospitalization rate (21.5% vs. 45.8%, $P = 0.035$).

Recurrence

CRBSI recurred in 12 of 75 patients (16%) after a median of 2.6 months (IQR 0.7–18). In multivariable analysis, ferritin > 500 ng/ml, albumin < 3.5 g/dl, and uric acid < 2.5 mg/dl were independently associated with recurrence.

Catheter outcomes

Included management strategies, with catheter removal in 46 patients (61.3%), guidewire exchange in 18 (24%), and salvage in 14 (18.6%). However, outcomes differed significantly between patients with primary and recurrent infections (49% vs. 75%, respectively; $P = 0.02$).

Mortality

One-year all-cause mortality was 28%. Higher mortality rates were significantly linked to several factors: longer dialysis duration ($P = 0.07$), lower body weight ($P = 0.01$), use of catheter salvage ($P = 0.029$), elevated neutrophil counts ($P < 0.0001$), hypoalbuminemia ($P = 0.004$), and hypokalemia ($P = 0.04$).

DISCUSSION

In this retrospective cohort of hemodialysis patients with tunneled catheters, the overall infection rate was 1.55 per 100 patient-months, with high hospitalization rates and a 1-year mortality rate of 28%. The microbiologic spectrum showed that Gram-positive organisms are common, consistent with other studies [16,17], but there was also a significant presence of Gram-negative organisms, including pseudomonas. This high prevalence of Gram-negative bacteremia is unusual for hemodialysis CRBSI. Multiple factors probably contribute to this result and could result from the high morbidity among in-center hemodialysis patients. However, these findings highlight the complexity of infection prevention and empiric therapy in catheter-dependent hemodialysis populations. The most consistent factors associated with recurrence and mortality in our cohort were nutritional and inflammatory markers.

Hypoalbuminemia and elevated ferritin were independently linked to recurrence. Hypoalbuminemia and high neutrophil counts were also associated with mortality. These markers likely reflect broader illness severity, including malnutrition, chronic inflammation, co-morbidities, and frailty rather than direct causal mechanisms alone, making these variables markers of vulnerability rather than definite biological drivers [18]. These findings may support more comprehensive follow-up and preventative measures in patients with poor nutritional and inflammatory profiles.

Modern preventive catheter-care practices, such as CHG exit-site dressings and taurolidine-based locks, were not associated with reduced recurrence or 1-year mortality in this cohort. However, CHG dressings were linked to a lower hospitalization rate. This finding might be due to limited statistical power and the high burden of Gram-negative infections, for which some preventive strategies, such as CHG dressings and taurolidine-heparin locks, may be less effective [9-11]. Given the high prevalence of Gram-negative pathogens, strategies targeting Gram-negative colonization and biofilm formation should be further explored. Catheter salvage was linked to higher mortality. However, this association should not be interpreted as evidence of harm from catheter salvage itself but rather because of salvage being chosen for frailer patients, those with limited vascular access options, or situations where catheter removal was less feasible. Future studies should examine standardized decision pathways for catheter salvage versus removal and better define outcomes based on pathogen type and patient risk profile [19,20].

This study has several limitations, including its retrospective design, single-center setting, and modest sample size. In addition, we did not include a comparator group for non-catheter-related bloodstream infections (CRBSI), which limited our ability to identify predictors of infection. Thus, the identified variables should be interpreted as factors associated with outcomes among patients who have already developed CRBSI, not as predictors of its occurrence. Clinicians made hospitalization decisions, so the results are descriptive rather than prescriptive. Nonetheless, this dataset provides valuable insights into real-world outcomes for a catheter-dependent hemodialysis population managed under consistent unit protocols.

CONCLUSIONS

Among hemodialysis patients with tunneled catheters and CRBSI, recurrence and mortality were most strongly associated with nutritional and inflammatory status as markers of vulnerability. CHG exit-site dressings were associated with fewer hospitalizations, but additional strategies, particularly those targeting Gram-negative infections, are needed to improve outcomes.

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Capsule

Parkinson's disease as a somato-cognitive action network disorder

To investigate the role of the somato-cognitive action network (SCAN) in Parkinson's disease (PD) pathophysiology and treatments (medications, deep-brain stimulation [DBS], transcranial magnetic stimulation [TMS], and MRI-guided focused ultrasound stimulation [MRgFUS]), **Ren** and colleagues built a large (n=863), multimodal, multi-intervention clinical imaging dataset. Resting-state functional connectivity revealed that the substantia nigra and all PD DBS targets (subthalamic nucleus, globus pallidus, and ventral intermediate thalamus) are selectively connected to the SCAN rather than to effector-specific motor regions. Importantly, PD was characterized by specific hyperconnectivity between the SCAN and the subcortex. The authors followed six PD cohorts undergoing DBS, TMS, MRgFUS, and levodopa therapy using precision resting-state functional connectivity and electrocorticography recording. Efficacious treatments reduced SCAN-to-subcortex hyperconnectivity. Targeting the SCAN instead of effector regions doubled the efficacy of TMS treatments. Focused ultrasound treatment benefits increased when the target was closer to the thalamic SCAN sweet spot. Thus, SCAN hyperconnectivity is central to PD pathophysiology and its alleviation is a hallmark of successful neuromodulation. Targeting functionally defined subcortical SCAN nodes may improve existing therapies (DBS, MRgFUS), whereas cortical SCAN targets offer effective non-invasive or minimally invasive neuromodulation for PD.

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Eitan Israeli

Capsule

B lymphocyte protein factories produced by hematopoietic stem cell gene editing

Engineered B cells have the potential to deliver therapeutic antibodies or other proteins within the body. **Hartweger** and co-authors modified hematopoietic stem and progenitor cells (HSPCs) with genes encoding specific. When transferred into mice, the HSPCs developed into B cells that responded to vaccination and produced therapeutic quantities of antibodies. The B cells underwent some somatic hypermutation, a process that diversifies the antibodies that they produce. However, transferring two populations of HSPCs, each modified to make a different antibody, provided an alternative solution for delivery of broadly neutralizing antibodies. HSPCs could be modified so that they differentiated into B cells that produced a fluorescent protein alongside an antibody, suggesting that this approach may also be leveraged to deliver other types of protein therapeutics.

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