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Original Article

Development of a risk prediction model for catheter-related bloodstream infection in hemodialysis patients based on identified risk factors

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Abstract: Objective: To analyze the risk factors for catheter-related bloodstream infection (CRBSI) in patients with deep vein indwelling hemodialysis catheters and construct a corresponding risk prediction model. Methods: Data were retrospectively collected from 154 patients who underwent temporary hemodialysis via an indwelling central venous catheter (CVC) between January 2023 and December 2024. One hundred patients who received hemodialysis via a Gracz arteriovenous fistula during the same period were also selected to analyze the impact of the dialysis method. Additionally, 58 maintenance hemodialysis patients with CVCs admitted from January to December 2022 were enrolled as a validation group. The incidence of CVC-related bloodstream infections was recorded. The risk factors of deep venous CRBSI were determined by multivariate Logistic regression analysis, and the risk prediction model was constructed and verified. Results: Univariate analysis identified diabetes mellitus, catheter indwelling time, femoral vein catheterization, age, and serum albumin level as significant influencing factors for CVC-associated bloodstream infection ($P < 0.05$). Multivariate logistic regression analysis confirmed that diabetes mellitus, prolonged indwelling time, and femoral vein placement were independent risk factors for CRBSI in maintenance hemodialysis patients ($P < 0.05$). The ROC curve for the constructed risk prediction model showed an area under the curve (AUC) of 0.783. The overall prediction accuracy of the model was 90.00%. Conclusion: Diabetes mellitus, prolonged catheter indwelling time, and femoral vein catheterization are independent risk factors for CRBSI in maintenance hemodialysis patients. The developed risk prediction model demonstrates good predictive performance.

Keywords: Maintenance hemodialysis, central venous catheter, catheter-associated bloodstream infection, risk factors, risk prediction models

Introduction

Hemodialysis (HD) serves as a vital life-sustaining renal replacement therapy for patients with end-stage renal disease, effectively removing metabolic waste and maintaining internal homeostasis, and has become the primary treatment modality for kidney failure [1, 2]. Ideal vascular access is the cornerstone for ensuring dialysis adequacy, reducing complications, and improving long-term prognosis. Currently, the autologous arteriovenous fistula (AVF) is recommended by international guidelines as the preferred vascular access for maintenance hemodialysis patients due to its lower infection rates, favorable long-term patency, and relative ease of use [3, 4]. However, the creation of an AVF is limited by patient vascular conditions (e.g., small or calcified vessels, prior vascular injury), and it requires a maturation period of several weeks to months, rendering it unsuitable for urgent dialysis initiation or for patients with exhausted peripheral vascular options [5]. Consequently, indwelling central venous catheter (CVCs) have become an indispensable alternative and often a necessary temporary or even long-term vascular access for a significant subset of hemodialysis patients, particularly those

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awaiting AVF maturation, with failed AVFs, or in critical conditions requiring immediate renal replacement therapy [6, 7]. Nevertheless, as a foreign body residing within the deep venous system, CVCs are inherently associated with a spectrum of complications, among which catheter-related bloodstream infection (CRBSI) stands out as the most frequent, serious, and potentially life-threatening adverse event [8].

The epidemiology of CRBSI in the hemodialysis population is alarming. Patients on maintenance hemodialysis exhibit an immune-compromised state due to uremia, coexisting comorbidities (e.g., diabetes), and frequent hospital exposures, making them exceptionally vulnerable to infections. Epidemiological data indicate that the risk of bloodstream infection in hemodialysis patients is 30-50 times higher than that in the general healthy population, with CVCs being the single strongest independent risk factor [9]. CRBSI not only leads to significant morbidity, including prolonged hospitalization, increased healthcare costs, and potential loss of the vascular access site, but also carries a substantial mortality risk. Severe cases can progress to metastatic infections such as endocarditis, osteomyelitis, or septic embolism, directly threatening patient survival [10, 11]. Moreover, recurrent infections contribute to the development of antimicrobial resistance, further complicating clinical management.

Given the severe clinical consequences, proactive prevention and early identification of high-risk patients are paramount. While clinical guidelines emphasize strict aseptic techniques during catheter insertion and care, and recommend the preferential use of AVFs, a considerable number of patients still rely on CVCs out of clinical necessity. Therefore, beyond adherence to universal care bundles, there is a pressing need for personalized risk stratification tools that can identify individuals at the highest risk of developing CRBSI before the infection occurs. Although previous studies have investigated various risk factors associated with CRBSI-including patient-related factors (e.g., diabetes, hypoalbuminemia, immunosuppression), catheter-related factors (e.g., insertion site, catheter duration), and care-related factors-most research remains fragmented. There is a notable lack of a comprehensive, integrated, and readily applicable clinical prediction model that synthesizes these multifactorial risks into a quantifiable score for routine clinical use [12, 13]. The innovative significance and clinical value of this study lie in addressing this critical gap. Moving beyond conventional single-factor analyses, we aim to systematically identify and integrate key clinical, laboratory, and catheter-management variables to develop and validate a multivariable risk prediction model specifically for CRBSI in hemodialysis patients with indwelling CVCs. The proposed model is intended to serve as a practical clinical tool, enabling healthcare providers to stratify patients into different risk categories upon catheter placement or during follow-up. This would facilitate targeted, intensified surveillance and preemptive interventions for high-risk individuals, such as more frequent dressing changes, patient education reinforcement, or consideration of early catheter exchange, while optimizing resource allocation. Ultimately, this study seeks to translate epidemiological insights into actionable clinical intelligence, contributing to a reduction in infection rates, improvement in patient safety and quality of life, and alleviation of the associated economic burden on the healthcare system.

Methods

Case selection

Data of 104 patients undergoing maintenance hemodialysis with an indwelling central venous catheter (CVC) at our hospital between January 2023 and December 2024 were collected as the risk prediction model group. Additionally, 30 maintenance hemodialysis patients admitted from January to December 2022 were selected as the validation group. This study was approved by the Ethics Committee of the First People's Hospital of Lanzhou City (Ethics Approval No: RGSZYYLL2020013). To clarify the differences in the core risk (CVC-related infection) across various vascular access types and to provide a more comprehensive clinical context, this study also included a reference cohort of 100 patients undergoing maintenance hemodialysis who used Gracz arteriovenous fistulas as their vascular access during the same period. This cohort was not involved in the construction or validation of the subsequent risk prediction model. Its primary purposes were:

(1) to compare baseline characteristics with the CVC cohort and assess the representativeness of the study cohort; and (2) to descriptively demonstrate the differences in infection incidence among patients with different vascular access types within the same medical center and time period, thereby highlighting the necessity of investigating CVC-related infection risks from a broader perspective.

Inclusion criteria: Aged between 18 and 80 years; Had complete clinical data; Underwent deep venous dialysis; Had a clearly identified cause of renal failure; Received CVC dialysis for more than 2 weeks; Underwent complete CVC implantation at our hospital. Exclusion Criteria: Incomplete clinical data; Involvement in medical disputes; Pregnancy or lactation; Presence of skin infection; Comorbidities requiring treatment for tumors or cardiovascular diseases; Diagnosis of cachexia.

Diagnostic criteria for CVC-related infection

Clinical diagnostic criteria (meeting any one of the following) [10]: Presence of at least one sign/symptom of infection (e.g., fever > 38°C, chills, hypotension) with no other identifiable source of infection, along with either of the following: Quantitative blood culture showing bacterial count from catheter-derived blood ≥5 times that from peripheral blood; Catheter-derived blood culture turning positive ≥2 hours earlier than peripheral blood culture. Clinical manifestations of infection along with pathogen growth in semi-quantitative (≥15 colonies) or quantitative ($\geq 10^2$ CFU) cultures from the catheter tip, segment, or connector, with matching pathogens in blood culture (preferably from a peripheral vein).

Definitive diagnostic criteria (all of the following must be met) [11]: Clinical manifestations of infection (e.g., fever, chills); At least one set of positive blood cultures (preferably simultaneous samples from catheter and peripheral vein); Exclusion of other infection sources (e.g., pneumonia, urinary tract infection); Concordance between catheter tip/fragment culture and blood culture results (matching species and susceptibility profile).

Based on the above criteria, among the 154 patients in this study, 29 were diagnosed with infection and 134 were non-infected.

Data collection and outcome measures

Patient demographic and clinical data were retrieved from the electronic medical record system, including baseline characteristics, hemoglobin levels, platelet counts, liver function parameters, and serum albumin levels as well as the parameters between different dialysis modalities and Distribution of pathogenic bacteria in the infected group.

Laboratory testing procedures: Fasting venous blood samples were collected at admission. A fully automated hematology analyzer (Sysmex XN-9000) was used for complete blood count analysis, including white blood cell (WBC) counts. Liver and kidney function, as well as lipid profiles, were assessed using a biochemical analyzer (Roche Cobas c702), measuring alanine aminotransferase (ALT), aspartate aminotransferase (AST), cholesterol, high-density lipoprotein, low-density lipoprotein, creatinine (SCr), and urea nitrogen (BUN). All assays were performed in strict accordance with the manufacturer's standardized operating procedures.

Statistical analysis

Statistical analysis was performed using SPSS version 23.0. Normally distributed continuous data were expressed as mean ± standard deviation (SD). Independent two-group comparisons for normally distributed data with homogeneous variance were conducted using paired t-tests or independent t-tests as appropriate. Categorical data were presented as n (%) and compared using the chi-square test. Multivariate logistic regression was employed to identify independent risk factors for deep vein indwelling catheter-related bloodstream infection. Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive performance of the model. A *P*-value < 0.05 was considered statistically significant.

Results

Comparison of baseline data between the two dialysis groups

No significant differences were observed between the two groups in terms of age, gender, primary disease, blood pressure, or electrolyte levels (all P > 0.05). Details are presented in **Table 1**.

Table 1. Comparison of baseline data of patients in different dialysis method groups

Variables	Central venous catheter group (n = 154)	Gracz AVP group (n = 100)	χ^2/t	P
Gender (Male)	82 (53.25%)	53 (53.00%)	0.002	0.964
Age (years)	49.7 ± 4.5	48.4 ± 4.6	1.499	0.137
Primary disease				
Diabetic nephropathy	61 (39.61%)	34 (34.00%)	0.484	0.486
Chronic glomerulonephritis	42 (27.27%)	28 (28.00%)	0.010	0.920
Hypertensive nephropathy	29 (18.83%)	20 (20.00%)	0.035	0.852
Chronic pyelonephritis	22 (14.29%)	18 (18.00%)	0.346	0.556
Blood calcium (mmol/L)	2.22 (1.76, 2.95)	2.18 (1.81, 3.02)	0.726	0.415
Blood glucose (mmol/L)	1.41 (1.06, 2.03)	1.46 (1.10, 2.12)	1.321	0.156
Parathyroid hormone (pmol/L)	41.26 ± 9.13	42.41 ± 10.18	0.674	0.502
Systolic blood pressure (mmHg)	127.57 ± 9.36	125.74 ± 8.55	1.171	0.244
Diastolic blood pressure (mmHg)	81.37 ± 6.78	79.43 ± 6.56	1.662	0.099

Table 2. Comparison of related indicators of dialysis methods between the two groups

Variables	Central venous catheter group (n = 154)	Gracz P group (n = 100)	t	P
Dialysis related indicators				
Kt/V	1.36 ± 0.12	1.47 ± 0.11	5.478	< 0.001
Urea reduction rate (%)	73.14 ± 6.50	77.62 ± 7.57	3.588	< 0.001
Vascular access blood flow (ml/min)	213.37 ± 21.56	227.65 ± 26.25	3.350	< 0.001
Structural parameters of the heart				
LVDd before establishment (mm)	47.45 ± 3.36	47.08 ± 3.42	0.581	0.562
LVDd after establishment (mm)	48.57 ± 4.53	50.62 ± 4.72	2.357	0.020
LVPWT before establishment (mm)	9.22 ± 1.13	9.43 ± 1.22	0.947	0.345
LVPWT after establishment (mm)	10.42 ± 1.58	11.37 ± 1.77	2.997	0.003
IVSTd before establishment (mm)	9.54 ± 2.24	9.31 ± 2.18	0.556	0.579
IVSTd after establishment (mm)	10.39 ± 2.30	12.53 ± 2.60	4.477	< 0.001

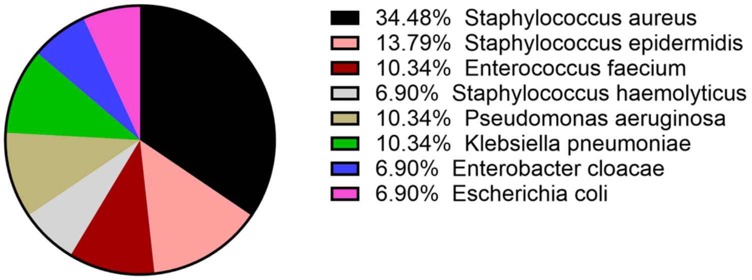

Figure 1. The distribution of infection types.

Comparison of relevant indicators between different dialysis modalities

The results indicated that the Gracz arteriovenous fistula group had significantly higher Kt/V, urea reduction rate, vascular access blood flow, and left ventricular cardiac indexes compared to the central venous catheter group (all P < 0.05). See **Table 2** for details.

Bloodstream infections associated with deep vein indwelling hemodialysis catheters

Among the 154 patients, 29 were confirmed with infection. Of these, gram-positive bacteria accounted for 65.52% of cases, while gram-negative bacteria accounted for 34.48%. The specific distribution of pathogen types is shown in **Figure 1**.

Drug resistance analysis of catheter-related bloodstream infections

Analysis of antimicrobial susceptibility in 29 infected patients revealed significant differences between Gram-positive and Gram-negative bacteria: Gram-positive bacteria showed high resistance rates (> 75%) to penicillin and first- and second-generation cephalosporins,

Table 3. Analysis of drug susceptibility test of infected patients in this group

Antibacterial drugs	Gram-positive bacteria Drug resistance rate (%, n = 19)	Antibacterial drugs	Gram-negative bacteria Drug resistance rate (%, n = 10)
Penicillin	90.48	Cefazolin	76.92
Cefazolin	87.5	Cefoperazone/sulbactam	75
Cefuroxime	77.78	Cefuroxime sodium	75
Clindamycin	61.9	Cefoxitin	55.56
Cefoxitin	50	Gentamicin	25
Gentamicin	35.71	Ceftriaxone	20
Amoxicillin/clavulanic acid	28.57	Ceftazidime	20
Levofloxacin	17.95	Tetracycline	11.76
Amikacin	16.22	Aztreonam	10
Quinupristin/dalfopristin	15.15	Levofloxacin	10
Tetracycline	9.52	Trimethoprim/Sulfamethoxazole	6.67
Rifampicin	2.38	Amikacin	0
Nitrofurantoin	5.26	Cefepime	0
Moxifloxacin	5.56	Meropenem	0
Vancomycin	0	Moxifloxacin	0
Linezolid	0	Imipenem	0

Table 4. Univariate analysis of deep vein indwelling hemodialysis catheter-related bloodstream infection

Project	Infected group (n = 29)	Non-infected group (n = 125)	Statistic Value	*P*-value
Age (years)	65.8 ± 10.2	58.3 ± 12.5	3.03	0.003
Catheter insertion site (n, %)			5.65	0.017
Femoral vein	18 (62.1%)	45 (36.0%)		
Internal jugular vein	11 (37.9%)	80 (64.0%)		
Catheter indwelling time (days, M (IQR))	28 (21-35)	14 (10-21)	-5.12	< 0.001
Serum albumin (g/L)	30.5 ± 4.1	35.2 ± 3.8	-5.67	< 0.001
Comorbid diabetes mellitus (n, %)	16 (55.2%)	35 (28.0%)	7.89	0.005
Gender (male, n, %)	15 (51.7%)	68 (54.4%)	0.07	0.792
Primary disease is diabetic nephropathy (n, %)	14 (48.3%)	50 (40.0%)	0.67	0.412
Dialysis time (month)	25.6 ± 20.1	28.3 ± 22.4	-0.60	0.551
Number of intubations (times)	1.5 ± 0.7	1.4 ± 0.6	0.80	0.423
Serum urea nitrogen (mmol/L)	25.3 ± 8.4	23.8 ± 7.9	0.95	0.341
Hemoglobin (g/L)	98.5 ± 15.2	101.3 ± 14.6	-0.97	0.332
Serum creatinine (μmol/L, M (IQR))	789 (645-912)	755 (623-880)	-1.06	0.287
Globulin (g/L)	28.5 ± 5.1	27.8 ± 4.7	0.73	0.467
Platelet count (×10^9/L)	185 ± 68	176 ± 72	0.64	0.528
White blood cell count (×10^9/L)	7.2 ± 2.3	6.9 ± 2.1	0.70	0.489

but remained fully susceptible to vancomycin and linezolid. In contrast, Gram-negative bacteria were completely susceptible to carbapenems (imipenem, meropenem), fourth-generation cephalosporins (cefepime), and amikacin, but exhibited high resistance to third-generation cephalosporins and certain β-lactam/β-lactamase inhibitor combinations. Details are provided in **Table 3**.

Univariate analysis of risk factors for catheter-related bloodstream infection

Univariate analysis identified the following factors associated with catheter-related blood-

Table 5. Assignment of independent variables

Argument	Index	Assignment
X1	Age	Raw value
X2	Serum albumin level	Raw value
X3	diabetes	1 = Exist; 0 = No
X4	Catheter indwelling time	Raw value
X5	Catheter indwelling site	1 = femoral vein; 2 = internal jugular vein

Table 6. Multivariate Logistic analysis of deep vein indwelling hemodialysis catheter-related bloodstream infections

Variable	B	S.E.	Forest χ^2	P	OR	95% CI
Age (for every additional 1 year)	0.021	0.016	1.723	0.189	1.021	0.990-1.054
Serum albumin (for every 1 g/L increase)	-0.108	0.062	3.034	0.082	0.898	0.795-1.014
Comorbid diabetes (yes vs no)	1.118	0.452	6.116	0.013	3.059	1.261-7.418
Catheter indwelling time (for each additional 1 day)	0.083	0.022	14.241	< 0.001	1.087	1.041-1.135
Catheterization site (femoral vein vs internal jugular vein)	1.352	0.483	7.835	0.005	3.866	1.501-9.956
Constant	-5.215	2.134	5.973	0.015	0.005	-

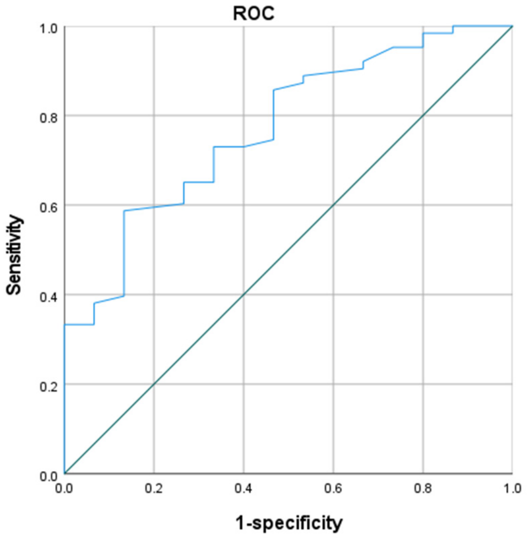

Figure 2. Prediction efficiency of a deep vein indwelling hemodialysis catheter-associated bloodstream infection model.

stream infection: Underlying diseases combined with diabetes, catheter indwelling time, catheter insertion site, age, and serum albumin level (all P < 0.05). No significant differences were found in gender, primary disease type, dialysis duration, number of catheterizations, serum urea nitrogen, hemoglobin, serum creatinine, globulin level, platelet count, or white blood cell count (all P > 0.05). See **Table 4**.

Multivariate logistic regression analysis of catheter-related bloodstream infection

Using the presence of catheter-related bloodstream infection (yes = 1, no = 0) as the dependent variable, multivariate logistic regression analysis confirmed that diabetes, catheter indwelling time, and catheter insertion site (femoral vein) were independent risk factors for CVC-related bloodstream infection in maintenance hemodialysis patients (P < 0.05). Results are shown in **Tables 5** and **6**.

Development of a risk prediction model for catheter-related bloodstream infection

Based on the significant variables identified in the multivariate logistic regression analysis, a predictive model for catheter-related bloodstream infection (CRBSI) was constructed. The final model formula is as follows: Logit(P) = -5.215 + 1.118 × Diabetes + 0.083 × Catheter Indwelling Time (days) + 1.325 × Femoral Insertion Site, where P represents the predicted probability of CRBSI.

Validation of the model

The performance of the prediction model was evaluated in both the derivation and validation cohorts. In the derivation cohort, the model achieved an area under the receiver operating characteristic (ROC) curve (AUC) of 0.876 (95% CI: 0.812-0.940). Using the optimal probability

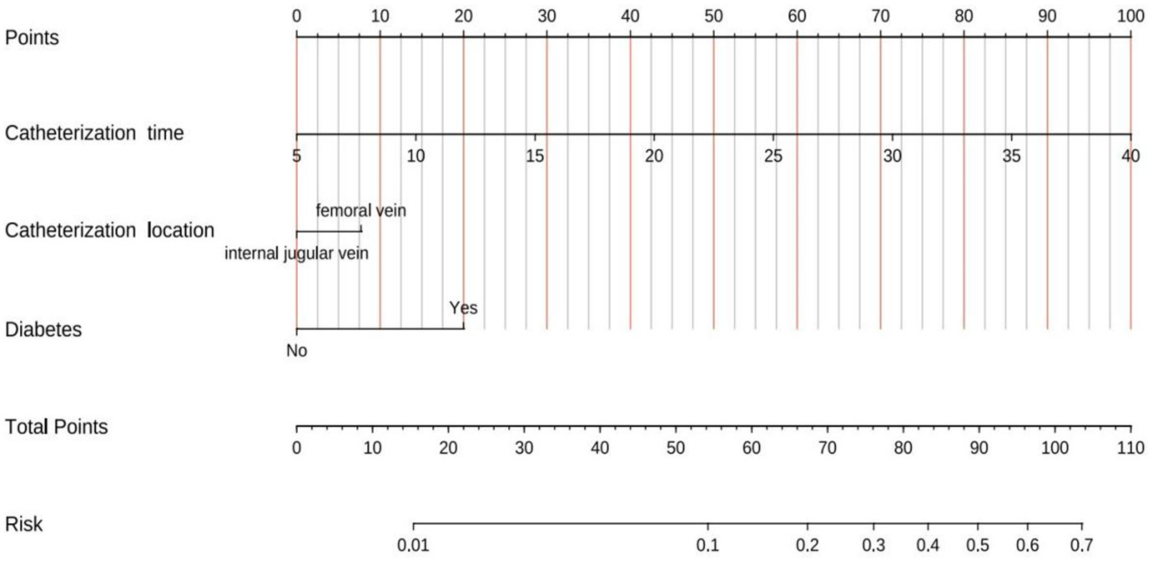

Figure 3. Nomogram prediction model for bloodstream infection associated with central venous catheter indwelling hemodialysis catheters.

cutoff of 0.42 (determined by the Youden index), the sensitivity and specificity were 86.2% (25/29) and 84.0% (105/125), respectively. When applied to the independent validation cohort (n = 58), the model maintained robust discriminative ability, with an AUC of 0.851 (95% CI: 0.734-0.968) and an overall accuracy of 89.7% (52/58), correctly identifying 10 of 12 infected patients and 40 of 46 non-infected patients. The model showed good calibration, as indicated by the Hosmer-Lemeshow test (χ^2 = 5.880, P = 0.554) and the calibration curve (**Figure 2**). For clinical application, a nomogram was developed to visualize individual risk prediction based on the three predictors (**Figure 3**).

Internal validation and clinical benefit of the prediction model

The model explained 75.2% of the variance (R^2 = 0.752) in the derivation set. Decision curve analysis (**Figures 4-6**) demonstrated that the model provided a significant net benefit across a wide range of threshold probabilities, supporting its clinical utility for CRBSI risk stratification. Detailed performance metrics of the model are summarized in **Table 7**.

Discussion

Recent epidemiological trends indicate a rising global incidence of various kidney diseases, potentially associated with lifestyle and environmental factors, with many chronic cases progressing to kidney failure [12, 13]. Although kidney transplantation rapidly addresses elevated creatinine levels, its application is limited by donor availability. Consequently, the majority of patients with renal failure currently depend on dialysis to sustain life [14]. Effective vascular access is essential for hemodialysis, with commonly used methods including autologous arteriovenous fistula, synthetic vascular grafts, and central venous catheters. In cases involving immature arteriovenous fistulas, poor vascular conditions, or heart failure, central venous catheter serve as the primary dialysis access. Previous studies have indicated that infection is a frequent complication of CVCs, which can lead to dialysis access failure and, in severe instances, patient mortality [15]. Therefore, investigating factors associated with catheter-related infections is crucial for improving the outcomes of hemodialysis access.

Prior research has established a strong correlation between catheter-related bloodstream infections (CRBSIs) and patient baseline characteristics, such as catheter insertion site, duration of indwelling, and comorbidities [16]. In line with these established findings, our study confirmed that catheter insertion site (femoral vein) and prolonged indwelling time

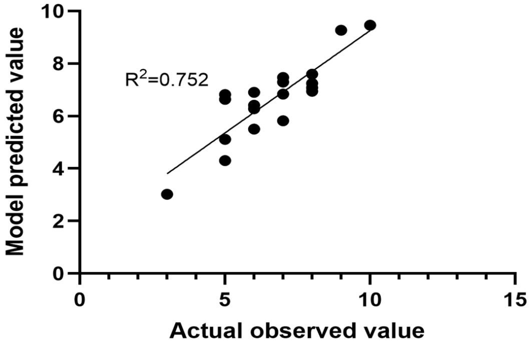

Figure 4. Nomogram prediction model proof.

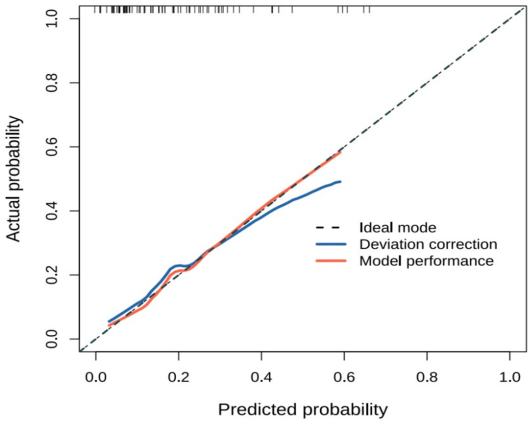

Figure 5. Decision curve analysis (DCA) for the nomogram prediction model.

are significant risk factors for CRBSI. The underlying mechanisms - such as higher bacterial load near the perineum for femoral catheters and fibrin sheath formation facilitating biofilm development over time - are consistent with earlier pathophysiological explanations [17-20]. Notably, our analysis further identified diabetes mellitus as an independent risk factor, reinforcing and extending previous observations. While prior studies have broadly associated comorbidities with infection risk, our results specifically highlight the role of diabetes in the context of hemodialysis-related CRBSI. This may be attributed to diabetes-related immune dysfunction, impaired microcirculation, and delayed wound healing, which collectively compromise local and systemic defenses against catheter-associated pathogens [21, 22]. Thus, while our findings generally align with the existing literature regarding anatomical and temporal risk factors, they provide additional specificity by emphasizing the contributory role of diabetes mellitus in this high-risk population. This underscores the importance of integrating comorbidity management - particularly glycemic control - into comprehensive CRBSI prevention strategies for maintenance hemodialysis patients.

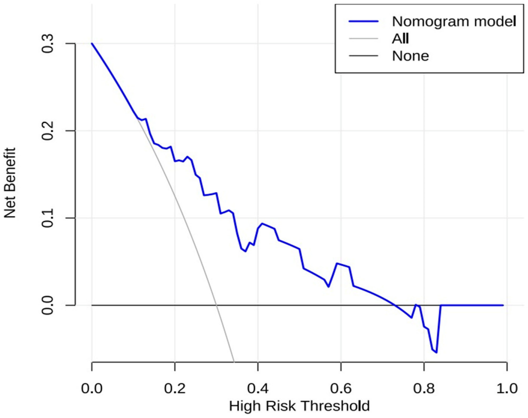

Figure 6. DCA of the nomogram prediction model for CRBSI. DCA, Decision Curve Analysis.

Table 7. Comparison of predicted variance of deep vein indwelling hemodialysis catheter-related bloodstream infection prediction with actual samples

Actual infection	Predicting infection		Total
	Not	Yes	
not	105	20	125
Yes	4	25	29
total	109	45	154

Prediction models based on readily available clinical variables have demonstrated considerable utility in previous investigations [23]. The model developed in this study - incorporating catheter site, indwelling time, and diabetes - exhibits strong applicability for several reasons. First, all three variables are routinely documented in clinical practice, objective, and easily accessible, which facilitates implementation across diverse healthcare settings. Second, these factors are well-established independent risk factors for CRBSI, supported by substantial evidence, thereby ensuring the model's theoretical robustness and predictive reliability - a conclusion also reflected in prior literature [24, 25].

In line with previous reports, our findings reveal distinct resistance patterns between gram-positive and gram-negative bacteria. Gram-positive isolates showed high resistance to penicillin and early-generation cephalosporin (> 75%) but remained fully susceptible to vancomycin and linezolid. These results underscore the importance of targeted antimicrobial therapy to enhance treatment efficacy in clinical practice [26, 27].

This study has several limitations. First, as a retrospective single-center analysis, it is susceptible to selection and information bias. Second, the relatively limited sample size may restrict the generalizability of the findings. Furthermore, the study did not account for the influence of antimicrobial therapies on infection outcomes, which should be addressed in future research. Although the prediction model demonstrated good performance in internal validation, its development and validation were based on data from a single medical center. While a temporally split validation cohort was used to enhance robustness, the model has not yet been externally validated with multicenter data. Variations across institutions - such as differences in patient demographics, catheter insertion and maintenance protocols, and local pathogen prevalence and resistance patterns - may affect the model's generalizability. Therefore, the next critical step will be to conduct external validation of this model using prospective, independent cohorts from multiple centers. This will further confirm its broad applicability and reliability across diverse clinical settings and provide higher-level evidence to support its eventual clinical translation and implementation. Although the prediction model demonstrated good performance in internal validation, its development and validation were based solely on data from a single medical center. While a temporally split validation cohort was used to enhance robustness, the model has not yet undergone external validation with multicenter data. Furthermore, due to the limitations of retrospective data, this study did not include key procedural and material-related variables that may influence the occurrence of CRBSI, such as catheter type (single-lumen/double-lumen), operator experience, and antibiotic lock therapy strategies. The main reasons for this omission are incomplete historical records or challenges in standardizing and quantifying such information. Differences across institutions in patient demographics, local clinical protocols, and the aforementioned procedural details may affect the generalizability of the model. Therefore, the next critical step is to systematically collect more comprehensive variables through a multicenter prospective design and conduct external validation of the model to further confirm its applicability and reliability across diverse clinical settings.

In conclusion, the risk prediction model constructed in this study demonstrates good predictive value for CRBSI in patients with deep vein indwelling hemodialysis catheters. Diabetes, prolonged catheter indwelling time, and femoral insertion site were confirmed as independent risk factors. Clinically, selecting the internal jugular vein for catheterization and strengthening glycemic control may help reduce the incidence of CRBSI and prolong the functional lifespan of dialysis catheters.

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Disclosure of conflict of interest

None.

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