Iranian Heart Journal; 2026; 27 (2)

Original Article

A Longitudinal Study of Catheter-Related Infections: Challenges in Diagnosis and Management

Shokoufeh Hajsadeghi[1], MD; Seyed Masoud Musavian[2], MD; Shima Loni[3], MD; Ali Mehrakizadeh[4], MD; Shayan Mirshafiee[4*], MD

ABSTRACT

Background: Central venous catheters (CVCs) are essential for vascular access but are associated with catheter-related bloodstream infections (CRBSIs), which can cause significant morbidity and mortality, particularly among hemodialysis patients.
This study aimed to investigate risk factors for CVC infections, evaluate the role of echocardiography in diagnosis and prognosis, and assess outcomes of different catheter management strategies.

Methods: A longitudinal study of 166 patients with confirmed CVC infections was conducted at Rasoul Akram Hospital, Tehran, Iran, from 2014 through 2022. Data included demographics, comorbidities, catheter site/duration, microbiological cultures, echocardiographic findings, and treatment outcomes. Statistical analyses included the χ^2 test, the *t* test, ANOVA, and regression methods using SPSS, version 26.

Results: Participants had a median age of 58 years (IQR, 45–67), and 54.8% were women. Fever was the most common presenting symptom (52.4%). Vegetations were detected in 52 patients (46.4%), most commonly at the catheter site. No significant difference in mortality was found between percutaneous and surgical catheter removal methods (P = 0.26). Vegetation size was not associated with mortality (P = 0.516). Patients with diabetes and transfusion history had longer hospital stays. Recurrence of infection was highest (37.9%) in those managed without catheter removal.

Conclusions: Echocardiography plays a critical role in the diagnosis and prognosis of CVC infections. Catheter removal, whether percutaneous or surgical, did not influence in-hospital mortality, even in cases with large vegetations. However, failure to remove infected catheters increased the recurrence risk. ***(Iranian Heart Journal 2026; 27(2): 54-64)***

KEYWORDS: catheter infection; echocardiography; catheter removal; endocarditis; longitudinal study

[1] Research Center for Prevention of Cardiovascular Disease, Institute of Endocrinology and Metabolism, Iran University of Medical Sciences, Tehran, IR Iran.
[2] Department of Cardiology, Rasoul Akram Hospital, Iran University of Medical Sciences, Tehran, IR Iran.
[3] Department of Internal Medicine, Tehran University of Medical Sciences, Tehran, IR Iran.
[4] Department of Cardiology, Tehran University of Medical Sciences, Tehran, IR Iran.

***Corresponding Author:** Shayan Mirshafiee, MD; Department of Cardiology, Tehran University of Medical Sciences, Tehran, IR Iran.
Email: Shayanmirshafiee@gmail.com **Tel:** +989127882166

Received: May 13, 2025 **Accepted:** January 29, 2026

Central venous catheters (CVCs) are widely used in modern medicine to provide stable and reliable vascular access for various medical procedures. Nonetheless, CVC use also carries the risk of life-threatening complications, particularly infection at the insertion site. These infections can result in prolonged hospitalization and increased mortality rates, making them a significant concern in healthcare settings.[1-4] An exit-site infection is characterized by purulent discharge, which may occur with or without erythema of the skin. In contrast, a tunnel infection is defined by clinical inflammation or ultrasonographic evidence of fluid collection along the catheter tunnel with at least 2 cm from the exit site. These 2 conditions may present either independently or concurrently.[5-8] In this context, clinical judgment is of paramount importance. For instance, a positive blood culture, in the absence of clinical or ultrasonographic findings, is not classified as a CVC infection.[9, 10]

Although the term “catheter-related infection” is frequently employed, it does not provide a clear distinction between infection and colonization. Catheter-related bloodstream infections (CRBSIs) are a primary cause of hospital septicemia in many countries, including the United States.[11-13] The diagnosis of CRBSIs involves identifying at least 2 pairs of simultaneous positive cultures, 1 from the blood and 1 from the catheter surface.[13-16] Hemodialysis patients, in particular, are highly susceptible to these infections due to their reliance on CVCs for vascular access. The mortality rate associated with CRBSIs in hemodialysis patients is alarmingly high and can range from 2.5 to 5.5 per 1000 catheter-days and they are more likely to be readmitted.[17-20] In addition to the burden on patient health and well-being, CRBSIs impose substantial economic costs on healthcare systems. Estimates suggest that there are between 250,000 and 500,000 catheter-related infections annually in the United States alone, resulting in significant healthcare expenses averaging $25,000 per infection.[12, 21, 22] CVC infections can result from bacterial colonization within the catheter, insertion site, or septicemia. The prevalence of CVC infections is approximately 43%, potentially leading to thrombosis formation.[23] The occurrence of CVC infections is influenced by various factors such as the operator’s expertise, duration of catheter use, sterilization levels, catheter location (eg, internal jugular vein or femoral vein), sex differences (higher prevalence in women), antibiotic selection, postoperative care, utilization of antimicrobial coated catheters, and ultrasound-guided insertion.[12, 24-27] Echocardiography is an important tool in catheter-related-infection management. Transthoracic echocardiography (TTE) is advised for individuals with *Staphylococcus aureus* bacteremia, while transesophageal echocardiography (TEE) is necessary to exclude endocarditis in patients with CRBSIs and certain cardiac conditions like prostatic heart valves, pacemakers, or ICDs, or persistent bacteremia.[28-31]

The objective of this study was to investigate the risk factors contributing to CVC infections and evaluate the influence of echocardiography and laboratory findings in incidence, prevention, and treatment outcomes. Additionally, by exploring infection process, we aimed to advance understanding and decrease infection rates, complications, mortality, and healthcare expenses.

METHODS

Study Design and Setting

This was a descriptive longitudinal study conducted at Rasoul Akram Hospital, Tehran, Iran, between January 2014 and December 2022.

Participants

A total of 500 patients admitted with suspected catheter-related infections were screened. Exclusion criteria included patients with Gore-Tex peritoneal catheter/AV fistula infections (n = 208), alternate final diagnoses (n = 78), and incomplete records (n = 48). The final study cohort comprised 166 patients with confirmed CVC infections. Inclusion criteria included clinical suspicion of systemic infection (fever or chills during hemodialysis) with the exclusion of other causes (negative urine culture or normal chest radiograph) and positive blood/catheter culture or new vegetation on echocardiography.

Data Collection

Data were extracted from medical records using a standardized checklist, including demographics (age and sex), clinical data (comorbidities, prior transfusions, and end-stage renal disease), catheter details (site, duration, and management), microbiology (blood/catheter cultures), echocardiography (TTE/TEE results and vegetation characteristics), and outcomes (mortality, recurrence, and hospitalization duration).

Variables considered were exposure (catheter sites, comorbidities, and vegetation size), outcome (in-hospital mortality, recurrence, and length of stay), and potential confounders (age, diabetes, and transfusion history).

Statistical Analysis

SPSS, version 26, was used. Normality was assessed with the Kolmogorov-Smirnov test. Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range [IQR]). Categorical variables were presented as frequencies (%). Associations were tested using the χ^2, *t*, Mann-Whitney *U*, and Pearson/Spearman correlation tests and ANOVA. Significance was set at a *P* value of less than 0.05. Missing data were excluded pairwise.

Ethics

This study was approved by the Ethics Committee of Iran University of Medical Sciences (IR.IUMS.FMD.REC.1400.352). Informed consent was waived due to the retrospective design of this study.

RESULTS

Descriptive findings

Women accounted for 54.8% (95% CI, 47.2–62.2%) of the subjects, with fever being the most common initial presentation at 52.4% (95% CI, 44.8–59.9%). The median age of the cohort was 58 years, with an IQR of 45 to 67. A majority of catheters were implanted in the jugular vein (77.7%; 95% CI, 70.8–83.4%). The most frequently observed underlying condition was end-stage renal disease, followed by hypertension and ischemic heart disease.

In 11.4% (95% CI, 7.5–17.2%) of individuals, both blood and catheter cultures yielded negative results. Among them, 6.0% (95% CI, 3.3–10.7%) had unrecorded blood or catheter culture results, while 4.8% (95% CI, 2.5–9.2%) had missing data for both cultures; the final diagnosis for some of these patients was determined by the presence of new vegetation observed in TEE. Subsequently, the infectious catheter was removed in 17/19 (89.5%; 95% CI, 68.6–97.1%) of these culture-negative cases, leading to improvement in fever and symptoms.

Within the study population, 17.5% (95% CI, 12.4–24.0%) of patients were managed with intravenous antibiotics without catheter removal, while 74.1% (95% CI, 66.9–80.2%) underwent percutaneous catheter removal without the requirement for open surgery. Furthermore, 8.4% (95% CI, 5.1–13.7%) underwent catheter removal via open surgery. Within the 2 patient groups where catheters were removed, the meantime interval from admission to catheter removal was 7.1 days (SD, 6.9; range: 0–29 d). A new CVC was placed for 126/166 patients (75.9%; 95% CI, 68.9–81.8%), with an average time interval of 1.3 days (SD = 1.5 d) between the removal of the primary infectious catheter and the implantation of the new catheter.

During the hospitalization period, 112/166 patients (67.5%; 95% CI, 60.0–74.1%) underwent TTE, while 64/166 patients (38.6%; 95% CI, 31.5–46.1%) had TEE. TTE was conducted before TEE for all patients who underwent both procedures (Table 1).

The median follow-up duration for the cohort was 24 months (IQR, 12–36; range: 1–96 mon). During this period, 19 patients (11.4%) experienced recurrence of catheter infection, with a mean interval of 3.8 months (SD = 3) from the initial hospitalization.

Table 1. Quantitative transesophageal and transthoracic echocardiographic findings

Variable		Frequency (%)	Mean (SD)
Tricuspid regurgitation gradient (mm Hg)		-	33.4 (9.9)
Systolic pulmonary artery pressure (mm Hg)		-	39.5 (12.2)
Left ventricular ejection fraction (%)		-	51.4 (8.6)
Left ventricular diastolic diameter (cm)		-	4.7 (0.8)
Left atrial diameter (cm)		-	3.5 (0.8)
Presence of Vegetation	Yes	52 (42.6%)	
	No	70 (57.4%)	
Number of Vegetations		-	0.5 (0.7)
Vegetation diameter (mm)		-	17.6 (13.7)
Vegetation thickness (mm)		-	7.6 (6.3)
Vegetation surface 9 (mm²)		-	192.5 (277.8)
Vegetation Location	Central vein or leads	31 (59.6%)	-
	Right atrium	12 (23.1%)	-
	Mitral valve	4 (7.7%)	-
	Tricuspid valve	1 (1.9%)	-
	Superior vena cava	4 (7.7%)	-

Subgroup analysis

Echocardiographic findings revealed 62 infectious vegetations in 52 patients (95% CI, 24.8–38.7%) (ie, 46.4% of those with available echocardiography data). Among these 52 patients, 28/52 (53.8%; 95% CI, 40.5–66.7%) tested positive for blood cultures. Catheter sampling was performed in 27/52 of them (51.9%; 95% CI, 38.7–64.9%), revealing positive catheter cultures in 12/52 (23.1%; 95% CI, 13.7–36.1%).

Among the study population, 9/166 patients (5.4%; 95% CI, 2.9–10.0%) died during their hospitalization, while the remaining individuals were discharged in satisfactory general condition. The study found no correlation between hospital mortality and CRP level and vegetation size. Nevertheless, age was identified as a factor related to mortality. Sex was not related to mortality ($P = 0.84$). The relationship between mortality and blood culture was investigated by dividing results into positive and negative groups; no relationship was found between mortality and positive or negative blood culture results. The statistical analysis revealed no statistically significant difference between mortality and vegetation size (≤ 10 mm, 11–20 mm, and > 20 mm) ($P = 0.516$). There was no statistically significant difference in mortality based on the action on the catheter in the 3 groups: no removal, percutaneous removal and surgical removal ($P = 0.26$).

The average duration of hospitalization was 14.8 days (SD = 13.3). Additionally, 19/166 patients (11.4%; 95% CI, 7.5–17.2%) experienced a recurrence of catheter infection, with an average time interval of

3.8 months (SD = 3) between the recurrence and the initial hospitalization.

Analysis of the actions taken on the infected catheter

Patients with vegetations were stratified into 3 categories based on the size of the largest vegetations in the echocardiography images (≤ 10 mm, 11-20 mm, and > 20 mm). Figure 1 presents the treatment protocols applied to patients with vegetations, categorized according to the size of vegetations. The action taken on the infected catheter (no removal and antibiotic treatment only, percutaneous removal, or surgical removal) did not show a significant relationship with the use of a new access during initial hospitalization or with the occurrence of death during hospitalization (P = 0.624 and P = 0.627, respectively). No significant difference was observed in the time intervals from admission to catheter removal and from catheter removal to access replacement between patients discharged in good general condition and those who died during hospitalization.

The average hospitalization duration differed significantly based on the treatment method of the infectious catheter, with patients undergoing surgical removal experiencing the longest hospital stay. The recurrence rate was notably highest at 37.9% for patients who did not have their infectious catheter removed, while patients who underwent percutaneous or surgical removal had recurrence rates of 5.7% and 7.1%, respectively. Patients who received a new access during initial hospitalization displayed a recurrence rate of 7.9%, whereas those without a new CVC placement had a notably higher rate of 22.5%.

Analysis of underlying diseases and past medical histories

Within this study, patients' underlying diseases did not exhibit a significant association with in-hospital mortality. There were no significant associations observed between the site of infected catheter, final diagnosis based on the type of infected catheter, need for IV nutrition, history of blood transfusion, previous CVC infection, and in-hospital mortality, with retrospective P values of 0.416, 0.898, 0.454, and 0.939.

Patients with diabetes or blood transfusion exhibited significantly prolonged hospitalization compared with those without (diabetes: 18.7 d [SD = 15.1] vs 14.1 d [SD = 12.6], P = 0.016 and blood transfusion: 19.5 d [SD = 15.3] vs 12.1 d [SD = 11.2]; P < 0.001).

Patients who died during hospitalization exhibited significantly lower mean platelet counts (107 × 1000 / mm^3 [SD = 72 × 1000 / mm^3]) and albumin levels (2.6 mg/dL [SD = 0.8 mg/dL]) compared with those who were discharged (platelets: 194 × 1000 / mm^3 [SD = 91 × 1000 / mm^3]; albumin: 3.2 mg/dL [SD = 0.7 mg/dL]) (P = 0.001 and P = 0.02, respectively).

Analysis of echocardiographic findings

There was no statistically significant difference observed in tricuspid regurgitation gradient, systolic pulmonary arterial pressure (SPAP), left ventricular ejection fraction (LVEF), left ventricular inner diameter in diastole (LVIDd), left atrial diameter, number of vegetations, diameter of the largest vegetation, and surface of the largest vegetation between patients discharged in good general condition and those who died during hospitalization.

The study did not identify a significant relationship between moderate or severe valvular and ventricular dysfunctions and in-hospital mortality. The corresponding P values can be found in Table 2.

Within the echocardiographic findings, only increased SPAP, number of vegetations, and diameter of the largest vegetation demonstrated a significant association with extended hospitalization. The average hospitalization duration was notably higher for patients with moderate-to-severe tricuspid regurgitation (26.9 [SD = 12.1] vs 17.4 [SD = 13.7]; *P* = 0.002) or vegetation in echocardiography (26.8 [SD = 15.6] vs 12.5 [SD = 8.1]; *P* < 0.001) compared with those without these findings. The presence of vegetation with diameters of 20 mm or greater in TEE was found to be significantly correlated with a longer mean hospital stay (34.3 [SD = 20.1] vs 22.8 [SD = 11.1]; *P* = 0.023). Among the qualitative echocardiographic findings, only the presence of moderate or severe tricuspid regurgitation was linked to the recurrence of catheter infection, with an odds ratio of 3.4 (95% CI, 1.03–11.76, *P* = 0.035). Further, among quantitative findings, only the mean diameter and surface of vegetations displayed significant differences between patients with recurrence and those without.

Table 2. Relationship between echocardiographic qualitative variables and in-hospital mortality

Variable	*P*	Variable	*P*
Mitral regurgitation	0.883	Left ventricular enlargement	0.466
Aortic insufficiency	0.803	Left ventricular hypertrophy	0.532
Aortic stenosis	0.802	Left ventricular systolic dysfunction	0.379
Tricuspid regurgitation	0.26	Left ventricular diastolic dysfunction	0.257
Pulmonary arterial hypertension	0.992	Left atrial enlargement	0.466
Right ventricular enlargement	0.17	Right atrial enlargement	0.169
Right ventricular dysfunction	0.174	Presence of vegetation	0.112

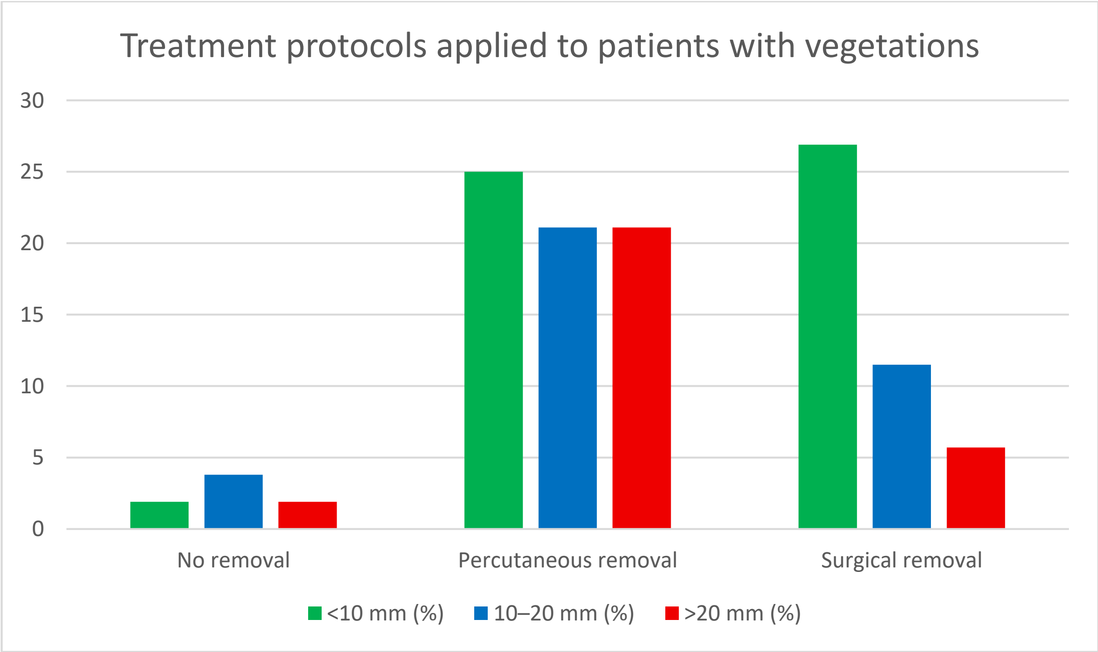

Figure 1. Treatment protocols applied to patients with vegetations

DISCUSSION

In this study, the diagnosis of catheter infection was established according to the 2009 IDSA (Infectious Disease Society of America) and 2020 update of central venous catheter-related infections in hematology and oncology guideline.[32-34] In instances where definitive diagnosis based on the guideline was challenging, the relief of symptoms following infected catheter removal or the detection of new vegetation in TEE indicated catheter infection as the most likely final diagnosis.

Previous studies have demonstrated the significant prognostic role of echocardiography. For instance, the presence of vegetations measuring 20 mm or more in infective endocarditis affecting the right heart structures is correlated with higher mortality rates.[35, 36] Furthermore, valvular disorders, reduced LVEF, and pulmonary hypertension are factors that may indicate a poorer prognosis.[37, 38] Echocardiography also plays a decisive role in determining treatment strategies, with timing being of paramount importance. A delay in conducting the initial TTE can increase the risk of septic embolism, valvular destruction, and the subsequent need for valvular surgery. On the other hand, early echocardiography may increase the chances of encountering false negative results.[39-44]

Considering hemodialysis as a significant risk factor for infective endocarditis,[45-47] cases involving catheter use and infections hold particular importance, especially in this population. Our study identified negative prognostic (eg, prolonged hospital stays and higher recurrence) indicators through echocardiographic findings. Key parameters included tricuspid valve insufficiency, vegetation presence (particularly on catheters), largest vegetation diameter, vegetation size of 20 mm or greater, and SPAP.

While it is common practice to refer patients with large right-sided vegetations, including CVC vegetations, for surgical lead extraction, the absence of data on percutaneous catheter removal, its techniques, and outcomes highlights a significant gap in our understanding. Despite the positive outcomes reported in studies on percutaneous vegetation removal for tricuspid valve endocarditis or pacemaker leads in high surgical risk patients,[48, 49] a significant gap exists in the guidelines for method of catheter removal in patients with vegetation on the CVC, highlighting the need for further research. Therefore, determination of the strategy and treatment required for catheter infection, as well as the decision-making process regarding the placement of a new catheter and appropriate timing for intervention, is crucial.[50, 51] It is noteworthy that IDSA guideline does not specify the method for catheter removal. Conversely, the process of removing the catheter is critical, as techniques like guidewire exchange, while reducing mechanical risks, can increase the risk of catheter site infection and bacteremia.[52-54]

In this study, the group where the infected catheter remained had the shortest hospital stay but the highest recurrence rate compared to percutaneous or surgical removal groups. The disparity in hospitalization duration within the catheter removal group stemmed from prolonged waiting periods for catheter removal.

In the study conducted by Zhong et al[55] on patients with suspected CRBSI who underwent catheter removal, it was observed that catheter reinsertion within the first 24 hours was associated with an increased 30-day mortality rate. It is important to note that patients with dialysis catheters were excluded from this study. Conversely, we found that replacing access during the same admission did not lead to increased recurrence rates and also demonstrated a decrease compared to individuals who did not undergo access replacement during the same hospitalization.

It is important to note that neither the approach taken for the infected catheter nor the replacement of new catheter during the same admission was linked to increased mortality during the hospitalization. This finding holds particular importance for vegetations larger than 2 centimeters, as percutaneous catheter removal demonstrated comparable mortality rates to the surgical method.

Limitations

Our main limitations include the retrospective nature of the study, its single-center design, and potential selection bias. Considering limitations of longitudinal studies and lack of sufficient researches in this field, it is necessary to conduct more powerful prospective multicentric studies with larger sample size to investigate the appropriate treatment strategy and position of echocardiography in the management of patients with catheter infection.

CONCLUSIONS

Echocardiography can play a crucial role in investigating and confirming infective endocarditis in patients with CRBSIs. It can aid in determining treatment strategies, assessing prognosis, and confirming diagnosis in complex cases, especially in patients with prior antibiotic use. Moreover, the method of catheter removal, whether surgical or percutaneous, does not appear to differ, even in individuals with vegetations larger than 2 centimeters.

Funding

No external funding was received.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

Data are available from the corresponding author upon reasonable request.

Ethical Approval

This study received approval from the Ethics Committee of Iran University of Medical Sciences (IR.IUMS.FMD.REC.1400.352).

REFERENCES

1. Dickinson, G.M. and A.L. Bisno, Infections associated with indwelling devices: concepts of pathogenesis; infections associated with intravascular devices. Antimicrobial agents and chemotherapy, 1989. 33(5): p. 597-601.
2. Raad, I., Intravascular-catheter-related infections. The Lancet, 1998. 351(9106): p. 893-898.
3. Banerjee, S.N., et al., Secular trends in nosocomial primary bloodstream infections in the United States, 1980–1989. The American journal of medicine, 1991. 91(3): p. S86-S89.
4. Eggimann, P., H. Sax, and D. Pittet, Catheter-related infections. Microbes and infection, 2004. 6(11): p. 1033-1042.
5. Szeto, C.-C., et al., ISPD catheter-related infection recommendations: 2017 update. Peritoneal Dialysis International, 2017. 37(2): p. 141-154.
6. Abraham, G., et al., Natural history of exit-site infection (ESI) in patients on continuous ambulatory peritoneal dialysis (CAPD). Peritoneal Dialysis International, 1988. 8(3): p. 211-216.
7. Flanigan, M.J., et al., Continuous ambulatory peritoneal dialysis catheter infections: diagnosis and management. Peritoneal dialysis international, 1994. 14(3): p. 248-254.
8. Greene, J.N., Catheter-related complications of cancer therapy. Infectious Disease Clinics, 1996. 10(2): p. 255-295.
9. Mun, S.J., et al., Role of echocardiography in uncomplicated Staphylococcus aureus catheter-related bloodstream infections. Medicine, 2021. 100(18): p. e25679.
10. J. Antony, S., Catheter related line sepsis resulting from Mycobacterium chelonae infection in an immunocompromised host. Infectious Disorders-Drug TargetsDisorders), 2015. 15(2): p. 135-137.
11. Smith, R.L., S.M. Meixler, and M.S. Simberkoff, Excess mortality in critically III patients with nosocomial bloodstream infections. Chest, 1991. 100(1): p. 164-167.
12. Safdar, N., D.M. Kluger, and D.G. Maki, A review of risk factors for catheter-related bloodstream infection caused by

percutaneously inserted, noncuffed central venous catheters: implications for preventive strategies. Medicine, 2002. 81(6): p. 466-479.

13. Bouza, E., et al., A randomized and prospective study of 3 procedures for the diagnosis of catheter-related bloodstream infection without catheter withdrawal. Clinical Infectious Diseases, 2007. 44(6): p. 820-826.

14. Fätkenheuer, G., O. Cornely, and H. Seifert, Clinical management of catheter-related infections. Clinical microbiology and infection, 2002. 8(9): p. 545-550.

15. Pearson, M.L. and H.I.C.P.A. Committee, Guideline for prevention of intravascular-device–related infections. Infection Control & Hospital Epidemiology, 1996. 17(7): p. 438-473.

16. Guembe, M., et al., Differential time to positivity (DTTP) for the diagnosis of catheter-related bloodstream infection: do we need to obtain one or more peripheral vein blood cultures? European journal of clinical microbiology & infectious diseases, 2012. 31: p. 1367-1372.

17. Oguzhan, N., et al., Locking tunneled hemodialysis catheters with hypertonic saline (26% NaCl) and heparin to prevent catheter-related bloodstream infections and thrombosis: a randomized, prospective trial. Renal Failure, 2012. 34(2): p. 181-188.

18. Chovanec, K., et al., Association of CLABSI with hospital length of stay, readmission rates, and mortality: A retrospective review. Worldviews on Evidence-Based Nursing, 2021. 18(6): p. 332-338.

19. Raad, I., Management of intravascular catheter-related infections. Journal of Antimicrobial Chemotherapy, 2000. 45(3): p. 267-270.

20. Wenzel, R.P. and M.B. Edmond, The evolving technology of venous access. The New England journal of medicine, 1999. 340(1): p. 48-50.

21. Scheer, B.V., A. Perel, and U.J. Pfeiffer, Complications of peripheral arterial catheters used for haemodynamic monitoring in anaesthesia and intensive care medicine. Critical Care, 2002. 6: p. 199-204.

22. Mermel, L.A., et al., Guidelines for the management of intravascular catheter-related infections. Infection Control & Hospital Epidemiology, 2001. 22(4): p. 222-242.

23. Boersma, R., et al., Thrombotic and infectious complications of central venous catheters in patients with hematological malignancies. Annals of oncology, 2008. 19(3): p. 433-442.

24. Lee, G.J., et al., A case-control study to identify risk factors for totally implantable central venous port-related bloodstream infection. Cancer Research and Treatment: Official Journal of Korean Cancer Association, 2014. 46(3): p. 250.

25. Hsieh, C.-C., et al., Analysis of risk factors for central venous port failure in cancer patients. World journal of gastroenterology: WJG, 2009. 15(37): p. 4709.

26. Lipitz-Snyderman, A., et al., Long-term central venous catheter use and risk of infection in older adults with cancer. Journal of clinical oncology, 2014. 32(22): p. 2351.

27. Parienti, J.-J., et al., Intravascular complications of central venous catheterization by insertion site. New England Journal of Medicine, 2015. 373(13): p. 1220-1229.

28. Baang, J.H., et al., Inpatient Diagnosis and Treatment of Catheter-Related Bloodstream Infection. 2023.

29. Narducci, M.L., et al., Usefulness of intracardiac echocardiography for the diagnosis of cardiovascular implantable electronic device–related endocarditis. Journal of the American College of Cardiology, 2013. 61(13): p. 1398-1405.

30. Pigrau, C., et al., Management of catheter-related Staphylococcus aureus bacteremia: when may sonographic study be unnecessary? European Journal of Clinical Microbiology and Infectious Diseases, 2003. 22: p. 713-719.

31. Hajsadeghi, S., S. Kalantari, and S. Mirshafiee, Uncommon site of Brucella

endocarditis in a double discordant heart. European Heart Journal-Case Reports, 2024. 8(11): p. ytae562.

32. Mermel, L.A., et al., Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 Update by the Infectious Diseases Society of America. Clinical infectious diseases, 2009. 49(1): p. 1-45.

33. Böll, B., et al., Central venous catheter–related infections in hematology and oncology: 2020 updated guidelines on diagnosis, management, and prevention by the Infectious Diseases Working Party (AGIHO) of the German Society of Hematology and Medical Oncology (DGHO). Annals of hematology, 2021. 100: p. 239-259.

34. Hentrich, M., et al., Central venous catheter-related infections in hematology and oncology: 2012 updated guidelines on diagnosis, management and prevention by the Infectious Diseases Working Party of the German Society of Hematology and Medical Oncology. Annals of Oncology, 2014. 25(5): p. 936-947.

35. Martín-Dávila, P., et al., Analysis of mortality and risk factors associated with native valve endocarditis in drug users: the importance of vegetation size. American heart journal, 2005. 150(5): p. 1099-1106.

36. Mihos, C.G. and F. Nappi, A narrative review of echocardiography in infective endocarditis of the right heart. Annals of Translational Medicine, 2020. 8(23).

37. Shmueli, H., et al., Right-sided infective endocarditis 2020: challenges and updates in diagnosis and treatment. Journal of the American Heart Association, 2020. 9(15): p. e017293.

38. Vilacosta, I., et al., The diagnostic ability of echocardiography for infective endocarditis and its associated complications. Expert review of cardiovascular therapy, 2015. 13(11): p. 1225-1236.

39. Microbiology, E.b.t.E.S.o.C., et al., Guidelines on the prevention, diagnosis, and treatment of infective endocarditis (new version 2009) The Task Force on the Prevention, Diagnosis, and Treatment of Infective Endocarditis of the European Society of Cardiology (ESC). European heart journal, 2009. 30(19): p. 2369-2413.

40. Okonta, K.E. and Y.B. Adamu, What size of vegetation is an indication for surgery in endocarditis? Interactive cardiovascular and thoracic surgery, 2012. 15(6): p. 1052-1056.

41. Young, W.J., et al., Echocardiography in patients with infective endocarditis and the impact of diagnostic delays on clinical outcomes. The American journal of cardiology, 2018. 122(4): p. 650-655.

42. Shafiyi, A., et al., Repeat transesophageal echocardiography in infective endocarditis: An analysis of contemporary utilization. Echocardiography, 2020. 37(6): p. 891-899.

43. Hajsadeghi, S., et al., The relationship between global longitudinal strain and pulmonary function tests in patients with scleroderma and normal ejection fraction and pulmonary artery pressure: a case–control study. The International Journal of Cardiovascular Imaging, 2020. 36: p. 883-888.

44. Hajsadeghi, S., et al., Comparison of Qanadli score with conventional risk stratifiers in non-massive pulmonary emboli. Journal of International Medical Research, 2024. 52(9): p. 03000605241276481.

45. Labriola, L. and M. Jadoul, Haemodialysis is a major risk factor for infective endocarditis. The Lancet, 2016. 388(10042): p. 339-340.

46. Pericàs, J.M., et al., Infective endocarditis in patients on chronic hemodialysis. Journal of the American College of Cardiology, 2021. 77(13): p. 1629-1640.

47. Sadeghi, M., S. Behdad, and F. Shahsanaei, Infective endocarditis and its short and long-term prognosis in hemodialysis patients: a systematic review and meta-analysis. Current Problems in Cardiology, 2021. 46(3): p. 100680.

48. George, B., et al., A novel approach to percutaneous removal of large tricuspid valve vegetations using suction filtration and veno-venous bypass: a single center experience. Catheterization and

Cardiovascular Interventions, 2017. 90(6): p. 1009-1015.

49. Rusia, A., A.J. Shi, and R.N. Doshi, Vacuum-assisted vegetation removal with percutaneous lead extraction: a systematic review of the literature. Journal of Interventional Cardiac Electrophysiology, 2019. 55: p. 129-135.

50. Boulet, N., et al., Central venous catheter-related infections: a systematic review, meta-analysis, trial sequential analysis and meta-regression comparing ultrasound guidance and landmark technique for insertion. Critical Care, 2024. 28(1): p. 378.

51. Cosme, V., et al., Central venous catheter-related infection: does insertion site still matter? A French multicentric cohort study. Intensive Care Medicine, 2024. 50(11): p. 1830-1840.

52. Cobb, D.K., et al., A controlled trial of scheduled replacement of central venous and pulmonary-artery catheters. New England Journal of Medicine, 1992. 327(15): p. 1062-1068.

53. Cook, D., et al., Central venous catheter replacement strategies: a systematic review of the literature. Critical care medicine, 1997. 25(8): p. 1417-1424.

54. Hecht, S.M., et al., Central venous catheter management in high-risk children with bloodstream infections. The Pediatric Infectious Disease Journal, 2020. 39(1): p. 17-22.

55. Zhong, Y., et al., Association of immediate reinsertion of new catheters with subsequent mortality among patients with suspected catheter infection: a cohort study. Annals of Intensive Care, 2022. 12(1): p. 38.