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Assessing the diagnostic value of the UBI-mTc 99-29-41 scan compared to blood culture for detecting hemodialysis catheter-related infection; a diagnostic value study

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ABSTRACT

Introduction: Catheter-related infection is one of the most important complications in patients with end-stage renal disease, often leading to increased mortality and prolonged hospitalization. Rapid and accurate diagnosis of these infections plays a crucial role in effective clinical management; however, the standard method of blood culture, despite its widespread use, has limitations such as being time-consuming. Technetium-99m labeled ubiquicidin peptide fragment, amino acids 29–41 (UBI-mTc 99-29-41) scintigraphy has emerged as a novel imaging technique that enables faster and more precise detection of catheter-associated infections.

Objectives: This study aimed to evaluate the diagnostic value of the UBI-mTc 99-29-41 scan compared with blood culture for identifying hemodialysis catheter infections.

Patients and Methods: This cross-sectional study was conducted on 54 hemodialysis patients with suspected catheter-site infection who were hospitalized at Labbafinezhad hospital in Tehran in 2025. Venous blood samples were collected from all participants for blood culture and they underwent UBI-mTc 99-29-41 scintigraphy assessment. Diagnostic performance measures, including overall accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), were calculated using standard statistical methods and Cohen's kappa coefficient to compare the diagnostic efficacy of UBI-mTc 99-29-41 scintigraphy with blood culture in detecting hemodialysis catheter infections.

Results: Compared with blood culture, the UBI-mTc 99-29-41 scan demonstrated an overall accuracy of 90.7%, sensitivity of 95.5%, specificity of 87.5%, PPV of 84%, NPV of 96.6%, false-positive rate of 12.5%, and false-negative rate of 4.5%. According to statistical standards, all parameters except the true positive ratio were significant, indicating the high diagnostic value of UBI-mTc 99-29-41 scintigraphy in identifying hemodialysis catheter infections.

Conclusion: UBI-mTc 99-29-41 scintigraphy demonstrated high diagnostic accuracy, sensitivity, and specificity compared to blood culture as a diagnostic standard reference in detecting hemodialysis catheter infections. These findings highlight its potential as a reliable and rapid diagnostic tool, supporting improved patient management and outcomes.

Original

Implication for health policy/practice/research/medical education:
The findings of this study indicated that technetium-99m labeled ubiquicidin peptide fragment, amino acids 29–41 (UBI-mTc 99-29-41) scintigraphy provides a high diagnostic accuracy in detecting hemodialysis catheter-related infections. The low rates of false-positive and false-negative results, along with statistically significant predictive values, highlight the reliability of this imaging method as a complementary or alternative diagnostic tool. Overall, these results suggest that the UBI-mTc 99-29-41 scan can play a valuable role in the timely and precise diagnosis of catheter infections, thereby improving patient outcomes and potentially reducing hospitalization duration compared with reliance on blood culture alone.

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Introduction

Catheter-related bloodstream infections (CRBSI) remain a significant and life-threatening complication in hemodialysis patients, contributing substantially to increased morbidity, mortality, and healthcare costs among this vulnerable population (1-4). Nearly 80% of patients initiating hemodialysis initially require a temporary or tunneled double-lumen catheter for vascular access, which paradoxically increases the risk of both exit-site and bloodstream infections compared to arteriovenous fistulas or grafts (5). The accurate and timely diagnosis of catheter-related infection is critical for prompt therapeutic intervention, as delays in diagnosis and treatment initiation can lead to severe septic complications, metastatic infections, and prolonged hospitalization (6).

Blood culture remains the conventional microbiological standard for diagnosing CRBSI in clinical practice, yet this traditional approach has inherent limitations that necessitate the exploration of alternative diagnostic modalities (6). While blood cultures collected from peripheral veins and catheter sources with differential time to positivity are recommended diagnostic methods, their clinical implementation in hemodialysis patients is frequently impractical due to the scarcity of available peripheral venous access and the desire to preserve remaining veins for future vascular access creation (2,7). Additionally, the sensitivity and specificity of blood culture methods can be compromised by factors including inadequate sampling technique, time delays in culture processing, prior antibiotic administration, and the propensity of biofilm-associated bacteria to exhibit reduced susceptibility to detection (8).

Radiolabeled antimicrobial peptide ubiquicidin 29-41 (UBI 29-41), labeled with technetium-99m (99mTc-UBI), represents an innovative nuclear medicine approach for infection imaging with potential advantages in differentiating bacterial infection from sterile inflammation at implanted medical device sites (9, 10). The 99mTc-UBI radiopharmaceutical specifically binds to the anionic bacterial cell membrane, enabling selective targeting of viable bacteria while minimizing uptake at sites of sterile inflammation, thereby offering superior specificity compared to conventional imaging modalities such as gallium scans or fluorodeoxyglucose positron emission tomography (11,12). While preliminary clinical studies have demonstrated promising diagnostic accuracy of 99mTc-UBI scintigraphy in musculoskeletal and periprosthetic infections with sensitivity and specificity indices exceeding 90% (13,14), its comparative diagnostic value relative to blood culture, specifically in the context of hemodialysis catheter-related infections, remains insufficiently characterized and represents an important gap in the current literature requiring investigation.

Objectives

This study aimed to evaluate the diagnostic accuracy of the UBI-mTc 99-29-41 scan in comparison with blood culture, the current reference standard, for detecting hemodialysis catheter-related infections. Specifically, the study aims to determine the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the UBI-mTc 99-29-41 scan, and to assess its potential role as a rapid, non-invasive diagnostic tool in clinical practice.

Patients and Methods

Study design and participants

This prospective diagnostic accuracy (cross-sectional) study enrolled adult hemodialysis patients with indwelling catheters and clinical suspicion of catheter-related infection, conducted in dialysis units at Labbafinezhad hospital in Tehran, Iran the year 2025. Participants underwent the UBI-mTc 99-29-41 scan as the index test, interpreted by nuclear medicine physicians blinded to microbiology results, and peripheral plus catheter-drawn blood cultures as the reference standard, processed by laboratory staff blinded to imaging findings.

Inclusion and exclusion criteria

Inclusion criteria comprised written informed consent, age ≥18 years, the presence of a tunneled or non-tunneled catheter, and clinical signs suggestive of infection. Exclusion criteria included refusal to participate, prior antibiotic therapy before blood culture and scan, contraindications to radiotracer administration, and failure to undergo both diagnostic procedures.

Data collection

Data were collected prospectively from adult patients undergoing hemodialysis with indwelling catheters who presented with clinical suspicion of catheter-related infection. After obtaining informed consent, demographic information, medical history, comorbidities, and catheter characteristics were recorded using standardized case report forms. Clinical data, such as history of catheter infection and type of catheter, were documented at enrollment. Each participant underwent both the UBI-mTc 99-29-41 scan and blood culture testing within 24 hours of suspicion of infection, with nuclear medicine physicians interpreting the scans blinded to microbiology results and laboratory staff processing cultures blinded to imaging findings. All results were entered into a secure database, and diagnostic accuracy indices, including accuracy, sensitivity, specificity, PPV, NPV, false positive rate, false negative rate, and positive and negative likelihood ratios, were calculated by comparing UBI-mTc 99-29-41 scan findings against blood culture as the standard reference.

Outcome measurement

The primary outcome of this study is the diagnostic

accuracy of the UBI-mTc 99-29-41 scan compared with blood culture for detecting hemodialysis catheter-related infection, measured by sensitivity, specificity, positive and negative predictive values, and likelihood ratios. Blood culture serves as the reference standard, with infection defined by positive peripheral and/or catheter-drawn cultures consistent with clinical signs, while the index test is considered positive when focal radiotracer uptake is observed at the catheter site according to predefined criteria. Both tests were performed within 24 hours of hospitalization, and results were interpreted by blinded nuclear medicine physicians and microbiology staff.

Statistical analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS; IBM Corp, USA), version 27, applying descriptive tests such as frequency and percentage, as well as inferential tests. To evaluate the diagnostic value of the UBI-mTc 99-29-41 scan compared with blood culture as the standard reference for diagnosing hemodialysis catheter infection, standard diagnostic accuracy methods were employed. Diagnostic performance was assessed by calculating indices including accuracy, sensitivity, specificity, PPV, NPV, false positive rate, and false negative rate. Agreement between the two diagnostic methods was evaluated using Cohen's kappa coefficient (values above 0.6 indicating substantial agreement). In addition, positive and negative likelihood ratios (LR+ > 10 and LR− < 0.1 considered strong indicators of diagnostic capability) were calculated. A *P* value less than 0.05 was considered statistically significant.

Results

The results indicated that the total number of patients studied was 54, with a mean age of 51.13 ± 15.89 years. The majority were male and had underlying diseases. Most patients had no previous catheter infection, and the majority used permanent catheters. Based on blood culture results, 40.7% of patients were diagnosed with catheter infection, and 59.3% were negative. In contrast, the UBI-mTc 99-29-41 scan identified 48.1% as positive and 51.9% as negative (Table 1).

The agreement between the UBI-mTc 99-29-41 scan and blood culture was 95.5% for positive cases and 87.5% for negative cases. The scan produced 12.5% false positives and 4.5% false negatives compared with blood culture. The overall accuracy was 90.7%. The PPV was 84% and the NPV was 96.6%. Cohen's kappa coefficient indicated that the agreement between the UBI-mTc 99-29-41 scan and the blood culture was statistically significant (Table 2).

Diagnostic value evaluation demonstrated that the UBI-mTc 99-29-41 scan demonstrated an overall accuracy of 90.7%, sensitivity of 95.5%, specificity of 87.5%, PPV of 88.4%, and NPV of 85.8%. The false positive rate was 12.5% and the false negative rate was 4.5%. The positive likelihood ratio was 7.64, and the negative likelihood ratio was 0.05. Except for the positive likelihood ratio, all values were statistically significant, confirming the high diagnostic value of the UBI-mTc 99-29-41 scan compared to blood culture in detecting hemodialysis catheter infection (Table 3).

Discussion

Our study demonstrates that UBI-mTc 99-29-41 scintigraphy offers a high diagnostic performance in detecting hemodialysis catheter-related infections, with high sensitivity, specificity, and overall accuracy compared to blood culture as a diagnostic standard

Table 1. Frequency distribution of demographic characteristics, clinical characteristics, and diagnostic findings in all studied patients

Variable	Sub-variable	Frequency	Percent
Gender	Male	34	63
	Female	20	37
Underlying disease	Diabetes	7	13
	Hypertension	9	16.7
	Cardiac disease	4	7.4
	History of kidney transplant	2	3.7
	Multiple underlying diseases	10	18.5
	No underlying disease	22	40.7
Previous catheter infection	No	45	83.3
	Yes	9	16.7
Type of hemodialysis catheter	Shaldon	5	9.3
	Permanent catheter	49	90.7
Catheter infection diagnosis by blood culture	Negative	32	59.3
	Positive	22	40.7
Catheter infection diagnosis by UBI-mTc 99-29-41 scan	Negative	29	51.9
	Positive	25	48.1
Variable		**Mean**	**SD**
Age (year)		51.13	15.89

SD: Standard deviation.

Table 2. Agreement between UBI-mTc 99-29-41 scan and blood culture in diagnosing hemodialysis catheter infection

Diagnostic method		Blood culture (standard reference)			Kappa	*P* value
		Positive N (%)	Negative N (%)	Total N (%)		
UBI-mTc 99-29-41	Positive N (%)	21 (95.5%) (84%)	4 (12.5%) (16%)	25 (100%)	0.812	<0.001*
	Negative N (%)	1 (4.5%) (3.4%)	28 (87.5%) (96.6%)	29 (100%)		
	Total N (%)	22 (100%)	32 (100%)			

*Cohen's kappa coefficient.

Table 3. Diagnostic value of UBI-mTc 99-29-41 scan compared to blood culture (Standard reference) in diagnosing hemodialysis catheter infection

Diagnostic method	Blood culture (Standard reference)	
	Metric	Value
UBI-mTc 99-29-41	Accuracy (%)	90.7
	Sensitivity (%)	95.5
	Specificity (%)	87.5
	PPV (%)	84
	False positive (%)	12.5
	NPV (%)	96.6
	False negative (%)	4.5
	LR+	7.64
	LR−	0.05

PPV; Positive predictive value, NPV; Negative predictive value, LR+; Positive likelihood ratios, LR−; Negative likelihood ratios

reference. The low false-negative and acceptable false-positive rates further emphasize its reliability as a diagnostic tool. Several prior investigations have confirmed the strong diagnostic performance of UBI-mTc 99-29-41 scintigraphy in infection detection. Akhtar et al reported a sensitivity of 100%, specificity of 80%, and accuracy of 94.4% in human infection imaging, highlighting its superiority over conventional methods such as blood culture and radiography (13). Sathekge et al found that UBI scintigraphy combined with SPECT/CT improved diagnostic confidence in musculoskeletal infections, achieving sensitivity above 90% (14). These findings are consistent with our study, which showed a sensitivity of 95.5% and a specificity of 87.5%, confirming the reproducibility of UBI scintigraphy's diagnostic value across different infection types.

The high sensitivity observed in our study underscores UBI-mTc 99-29-41's ability to detect infections even in early stages, which is critical for hemodialysis patients, where catheter-related infections can rapidly progress (14). The relatively low false-negative rate (4.5%) in our cohort is comparable to results reported in prosthetic joint infection models, where UBI scintigraphy showed minimal missed diagnoses (15). Furthermore, the acceptable false-positive rate (12.5%) reflects the tracer's specificity for viable bacteria, as highlighted by Garg et al, who noted that UBI does not accumulate in sterile inflammation or necrotic tissue (16). Collectively, these findings suggest that UBI scintigraphy may serve as a reliable adjunct to blood culture, particularly in cases where culture results are delayed or inconclusive.

Overall, our study corroborates previous evidence that UBI-mTc 99-29-41 scintigraphy is a highly accurate and reliable diagnostic tool for infection detection. The consistency of sensitivity and specificity values across diverse clinical settings, including musculoskeletal infections, demonstrates its broad applicability (14). For hemodialysis catheter-related infections, the method's rapid diagnostic capability offers significant clinical advantages over blood culture, potentially reducing morbidity and hospitalization duration. Overall, UBI-mTc 99-29-41 scintigraphy should be considered a valuable complementary diagnostic modality, with future studies warranted to validate its cost-effectiveness and long-term impact on patient outcomes across larger, multi-center cohorts.

Conclusion

The study demonstrates that UBI-mTc 99-29-41 scintigraphy offers a high diagnostic performance in detecting hemodialysis catheter-related infections, with high sensitivity, specificity, and overall accuracy compared to blood culture as a diagnostic standard reference. The low false-negative and acceptable false-positive rates

further emphasize its reliability as a diagnostic tool. Except for the true positive ratio, all statistical parameters were significant, underscoring the robustness of the findings. These results highlight the potential of UBI-mTc 99-29-41 scintigraphy as a valuable complementary or alternative method to blood culture, enabling earlier and more precise identification of catheter infections and thereby supporting improved patient management and outcomes.

Limitations of the study

This study has several limitations that should be acknowledged. First, the relatively small sample size of 54 patients from a single center may limit the generalizability of the findings to broader populations. Second, the descriptive-diagnostic design without randomization or control groups introduces potential selection bias and restricts causal inference. Third, reliance on blood culture as the sole reference standard, despite its known limitations in sensitivity and specificity, may affect the accuracy of comparative results. Additionally, the study was conducted in one hospital setting, which may not reflect variations in patient demographics, clinical practices, or infection prevalence in other institutions. Finally, the use of a single imaging modality interpreted by specific radiologists could introduce observer bias, and the lack of long-term follow-up prevents assessment of the prognostic value of UBI-mTc 99-29-41 scintigraphy.

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Authors' contribution

Conceptualization: Elmira Mahmoudi Chalmiani and Raedeh Bakhtiari.
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Supervision: All authors.
Validation: Shabnam Tehrani.
Writing–original draft: All authors.
Writing–review and editing: All authors.

Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical issues

The research was conducted in accordance with the Declaration of Helsinki. Informed written consent was taken from all participants. This study was conducted at Labbafinezhad hospital and was derived from the thesis work of Raedeh Bakhtiari (Thesis #43013913). It received ethical approval from the Ethics Committee of the School of Medicine at Shahid Beheshti University of Medical Sciences in Tehran, Iran, under code IR.SBMU.MSP.REC.1404.287 (available at: https://ethics.research.ac.ir/form/opibivt2b2m3w074.pdf). Besides, the authors have ultimately observed ethical issues (including plagiarism, data fabrication, and double publication).

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

While preparing this work, the authors utilized AI (Grammarly, Perplexity, and Copilot) to refine grammar points and language style. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the publication's content.

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