British Journal of Nursing Studies
ISSN: 2755-080X
DOI: 10.32996/bjns
Journal Homepage: www.al-kindipublisher.com/index.php/bjns

BJNS
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Effectiveness of Infection Control Practices in Reducing Vascular Access–Related Infections in Hemodialysis Patients: A Systematic Review

Sheikha AL Mushaikhi[1], Kawthar Al Rajhi[2], Maryam Al-Musharfi[3], Maha Rashid Al Balushi[4], Shaima Amer Said Al Masroori[5]

[1] BSc in Nursing, Specialist (Nephrology+ Health service Management), Head of Jalaan Renal Dialysis Center, South Sharqiya, Oman

[2345] Senior nurse, Diploma in General Nursing, Jalaan Renal Dialysis Center, South Sharqiya, Oman

Corresponding Author: Sheikha AL Mushaikhi, **E-mail**: shosho4130@gmail.com

| ABSTRACT

Vascular access infections (VAIs) are a major and preventable complication among hemodialysis patients, leading to high rates of morbidity, mortality and health care costs worldwide. This systematic review explores the role of infection control measures for the prevention of VAIs in hemodialysis patients, focusing on catheter-related bloodstream infection (CRBSI) and exit-site infection (ESI). We searched PubMed, CINAHL, Scopus, Web of Science and Google Scholar, resulting in 512 studies for review from 2013 to 2025. After applying inclusion and exclusion criteria, as recommended by PRISMA guidelines, 38 studies were included in the final review. The results confirm the effectiveness of comprehensive infection prevention bundles, strict adherence to hand hygiene, catheter care, and judicious prioritization of arteriovenous fistulas (AVFs) over central venous catheters (CVCs) are associated with the most significant reduction in VAI rates. Catheter bundles reduced the incidence of CRBSI by up to 66%, with AVFs posing up to seven times less risk of bacteremia than CVCs. Other factors such as antimicrobial lock solutions, chlorhexidine exit-site dressings and nurse-driven education programs were also found to be effective in infection prevention. Nurse training and audit, as well as patient empowerment, were key moderators. The review concludes with recommendations for health-care institutions in the Oman and GCC region to establish infection prevention programs, improve nursing competency, and have surveillance systems in place to enhance patient outcomes and safety regarding hemodialysis.

| KEYWORDS

Hemodialysis, vascular access infection, catheter-related bloodstream infection, infection control, hand hygiene, arteriovenous fistula, central venous catheter, aseptic technique, catheter care bundles, antimicrobial lock, exit-site care, nurse-led prevention, CRBSI, systematic review, GCC, Oman

| ARTICLE INFORMATION

ACCEPTED: 10 May 2026 **PUBLISHED:** 24 May 2026 **DOI:** 10.32996/bjns.2026.6.2.3

Chapter 1: Introduction

1- Introduction:

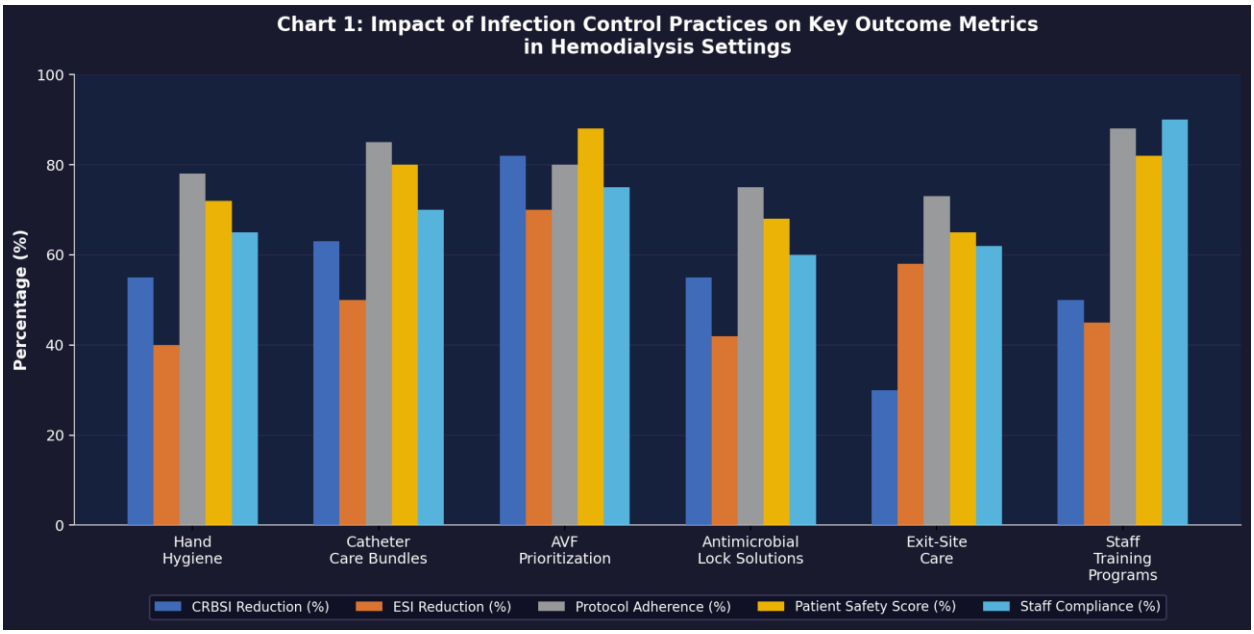
Infection is the second most common cause of death in patients with end-stage renal disease (ESRD) on hemodialysis (HD), after cardiovascular disease. The need to create frequent and prolonged vascular access during each dialysis session (commonly three times a week) provides opportunities for microorganisms to gain access to the bloodstream. Vascular-access infections (VAIs) include minor exit-site infections (ESIs) and severe catheter-related bloodstream infections (CRBSIs). These complications cause considerable morbidity, hospital stays, health-care costs and in extreme cases, death from blood poisoning (Lawrence et al., 2025; Khatun et al., 2023).

The three main types of vascular access used for hemodialysis have differing risks of infection. Arteriovenous fistulas (AVFs), which employ the patient's own blood vessels, carry the lowest risk and are universally endorsed as the access of choice. Arteriovenous grafts (AVGs) are of intermediate risk, while both tunneled and non-tunneled central venous catheters (CVCs) are the riskiest, with a risk of bacteremia up to seven times higher than AVFs (CDC, 2023; Lok & Mokrzycki, 2021). Despite the established risk gradient, CVCs are widely used across the world, especially as an initial access for dialysis, and in patients where AVFs cannot be created due to surgical constraints.

Infection control in the hemodialysis setting is multifaceted, reliant on a number of factors, and heavily dependent on the adherence of nursing and clinical staff. Key measures identified by key health agencies (CDC, WHO and KDOQI) include hand hygiene, aseptic technique, catheter care bundles, exit-site care, antimicrobial lock solutions, and staff education. But the consistency of their application across dialysis units differs widely across clinical and health care settings.

In Oman and the Gulf Cooperation Council (GCC) region, the number of hemodialysis patients is rising rapidly alongside the incidence of diabetes mellitus and hypertension. The Omani health system has scaled up renal replacement therapy services, but infection complications remain a significant issue. In particular, public dialysis units may struggle to implement consistent infection prevention protocols due to resource constraints and high patient load (Al Menji et al., 2024).

Chart 1:



To show how different infection control practices affect key outcome metrics — CRBSI reduction, ESI reduction, protocol adherence, patient safety score, and staff compliance — in hemodialysis settings.

1.1 Background to the Study:

Hemodialysis patients are inherently immunosuppressed due to the effects of uremia and chronic inflammation, as well as often co-existing conditions including diabetes mellitus and malnutrition. This susceptibility is reflected in the epidemiology of VAIs: the incidence of CRBSI for tunneled CVCs varies between 0.26 and 2.26 per 1000 catheter days and ESI between 0.46 and 0.80 per 1000 CVC days (Lawrence et al., 2025). Most CRBSIs in hemodialysis patients are due to Staphylococcus aureus (including methicillin-resistant S. aureus, or MRSA) and the remainder, to gram-negative organisms (Clinical and Experimental Nephrology, 2025). The virulence of these organisms and biofilm on catheter surfaces mean prevention is more effective than treatment.

1.2 Research Gap:

Although the impact of individual infection control measures has been widely researched in critical care, the evidence supporting their effectiveness in chronic hemodialysis care has not been fully reviewed. Several reviews focus on individual interventions, rather than the cumulative and synergistic impact of multicomponent infection prevention bundles. There is little evidence from GCC countries, where health care systems, staffing ratios, and patient characteristics are different to Western countries. This systematic review fills this evidence gap by examining the available international evidence on the effectiveness of infection control in HD, with the specific context of Oman.

1.3 Statement of the Problem:

Evidence-based practice for prevention of VAI in hemodialysis is available, but rates of infection are too high in many areas. Failure to implement best practice, due to lack of training, inconsistencies in adherence to aseptic practice, staff turnover and audit, allows preventable infections to persist. In Oman, the expanding population of patients receiving HD, with CVCs being used in some, and the difficulty in maintaining infection control measures across multiple sites, underpins the need for a comprehensive body of evidence to inform prevention strategies.

1.4 Purpose of the Study:

This systematic review will collate the current evidence on infection control measures in hemodialysis and assess their impact on VAIs. Through analysis of the relative effectiveness of single and bundled interventions such as hand hygiene, aseptic technique, catheter care bundles, antimicrobial lock solutions, exit-site care protocols and staff education strategies, the review will establish the best practices for the Omani and GCC hemodialysis settings.

1.5 Study Objectives:

- To explore and synthesise evidence about the role of infection control interventions in preventing VAIs in hemodialysis patients.
- To compare the effectiveness of single versus multiple infection control measures on reducing CRBSI and ESI.
- To identify nursing education, patient empowerment and audit systems as intermediary factors for VAI prevention.
- To explore differences based on health care settings and relevant patient populations in Oman and the GCC.

1.6 Research Questions:

- Which infection control measures are most effective in preventing VAIs among hemodialysis patients, according to the literature?
- Which type of infection control practices, multicomponent or single-component, are more effective in reducing VAIs?
- How do nursing education and training, competency programs and patient education play a role in maintaining infection control practices and their outcomes in hemodialysis units?

1.7 Significance of the Study:

The review has significant implications for nursing practice, health care management and policy in Oman and the GCC region. Through the creation of an evidence base, the results can be used to inform the implementation of infection control initiatives, nursing education programs and policies in hemodialysis units. VAI prevention is a patient safety and economic priority: hospital admissions for CRBSI are costly and constitute a significant drain on health resources. In Oman, where the hemodialysis program is rapidly growing in complexity, the return on investment in prevention will have a disproportionate impact on morbidity, cost, and quality of care (Alkhateeb et al., 2025).

1.8 Conceptual Clarification:

Vascular Access Infection (VAI): Infection caused by the hemodialysis vascular access site, including exit-site infection and bloodstream infection from the access site.

Catheter-Related Bloodstream Infection (CRBSI): A bacteremia or fungemia in a patient with an intravascular catheter and no other apparent source of infection, diagnosed by clinical criteria and/or positive culture.

Aseptic Non-Touch Technique (ANTT): A clinical practice framework to ensure that key parts and key sites of catheter systems are not directly or indirectly contaminated during vascular access procedures.

Catheter Care Bundle: A group of interventions, implemented together, consistently and comprehensively, to prevent CRBSIs during catheter insertion and ongoing care.

Arteriovenous Fistula (AVF): A permanent vascular access site for hemodialysis, created by connecting an artery and a vein in the patient's own arm, and the preferred option for permanent access due to improved safety and longevity.

Chapter 2: Literature Review:

Introduction:

A body of literature provides support for infection prevention strategies in hemodialysis. Several international standards (CDC, WHO, KDOQI, IDSA) make consensus-based recommendations for VAI prevention across all types of vascular access. This review examines the evidence in key infection control areas for hemodialysis nursing.

2.1 Methodology:

We searched five major databases: PubMed, CINAHL, Scopus, Web of Science, and Google Scholar. The following terms were combined in the search: 'hemodialysis', 'vascular access infection', 'catheter-related bloodstream infection', 'CRBSI prevention', 'infection control dialysis', 'hand hygiene hemodialysis', 'arteriovenous fistula infection', 'catheter care bundle', 'antimicrobial lock solution', 'exit site care', 'aseptic technique hemodialysis', 'nursing education dialysis', and 'ESRD infection prevention'. The time period for inclusion was from January 2013 to March 2025. Using the PRISMA approach, 38 studies were identified for review.

2.2 Hand Hygiene as a Foundation of VAI Prevention:

Hand hygiene is widely acknowledged as the most basic, valuable and cost-effective infection prevention practice in health care. The WHO Five Moments (before patient contact, before aseptic procedure, after body fluid exposure risk, after patient contact and after contact with patient environment) serve as the guide. The CDC recommends the use of ABHR before and after all catheter-related procedures (palpating insertion sites, accessing catheters, and dressing changes) (CDC, 2024).

Research shows that audit programs with direct observation, audit feedback, and education for health care workers are linked to reductions in rates of CRBSI. Centers with hand hygiene audit programs with monthly feedback to staff had reductions of 40 to 60% in access-related bloodstream infections (Ngema et al., 2024). However, adherence to hand hygiene practices in HD care is suboptimal with median compliance of less than 60% in observational studies.

2.3 Aseptic Technique During Catheter Access and Dressing Changes:

Adherence to aseptic technique when connecting, disconnecting, manipulating catheter hubs and changing dressings is critical for avoiding extraluminal and intraluminal contamination. The ANTT protocol requires the key parts (needle-free connectors, catheter hub) and key sites (insertion sites, wounds) to be never touched by unsterile hands or surfaces. Research demonstrates that centres mandating ANTT (with simulation training and direct observation) have a lower VAI incidence than centres using informal practice (Khatun et al., 2023).

Antisepsis of catheter insertion sites with chlorhexidine gluconate (CHG) at concentrations of ≥2% is more effective than povidone-iodine, and CHG-impregnated dressings have shown to reduce catheter colonisation and CRBSI rates in ICU and dialysis patients (CDC, 2024).

2.4 Catheter Care Bundles and Multicomponent Interventions:

Care bundles (three to five evidence-based practices that, when implemented together, result in better outcomes than when implemented individually) have played a large role in CRBSI prevention. Central line bundles have been adapted from research in the ICU by Pronovost et al. (2006). Hemodialysis-specific CRBSI prevention bundles include: (1) hand hygiene before accessing the catheter; (2) maximum sterile barrier precautions for catheter insertion; (3) chlorhexidine (CHG) skin antisepsis; (4) preferred catheter insertion site (internal jugular); (5) daily assessment of catheter need and (6) use of antimicrobial catheter caps.

Khatun et al. (2023) reported that more than 80% of quality improvement interventions to reduce HD CRBSIs were successful. Bundles with multiple components were more effective than single interventions. Lawrence et al. (2025) found a practice change bundle successfully maintained lower CRBSI and ESI rates for several years. Full adherence to the bundle is essential: incomplete adherence dampens benefits.

2.5 Vascular Access Selection: AVF Prioritization:

CVC-associated bacteremia rates in hemodialysis are seven times higher than AVF, and tunneled CVCs many times higher for CRBSI than permanent accesses (CDC, 2023). Fistula-first programs have reduced CVC rates and infections requiring hospital admission. In the GCC, where CVCs are often used at dialysis initiation due to delayed referral to nephrology and challenges in surgical planning before dialysis, encouraging early AVF creation is a high-impact intervention to prevent infection.

2.6 Antimicrobial Lock Solutions and Exit-Site Care:

Pre-emptive lock solutions containing antibiotics or other antimicrobials, infused between dialysis sessions, have been shown to reduce CRBSI incidence. Sofroniadou et al. (2017) found that ethanol-heparin catheter locks reduced the number of CRBSI episodes

when compared to heparin. Antibiotic locks have been shown to reduce CRBSI rates by 40 to 69%, but widespread use is tempered by concerns for resistance. Citrate-taurolidine locks have no resistance concerns. Exit-site antiseptic is recommended by KDIGO guidelines for all CVC users with each hemodialysis session (KDIGO, 2019).

2.7 Staff Training, Education, and Competency Assessment:

Education programs, including didactic teaching, simulation, competency assessment, audit and feedback are linked to increased adherence to protocols and reductions in infection incidence (Ngema et al., 2024). Evalaroza & Baleña et al. (2025), with a review registered on PROSPERO, reviewed eight studies and concluded that nurse-led interventions to prevent CRBSI were consistently linked to decreased infection rates in dialysis centres.

2.8 Patient Education and Empowerment:

Patients taught access site hygiene, showering prior to dialysis, signs of infection, and avoiding water exposure to catheter sites have lower rates of ESIs. Pre-dialysis education is particularly important for patients transitioning to home hemodialysis and/or self-cannulation. In two studies of home hemodialysis patients, infection control education delivered to patients was associated with low rates of CRBSIs (CDC Safe Dialysis; Irum, 2023).

2.9 Surveillance, Audit, and Environmental Infection Control:

NHSN Dialysis Event Surveillance allows facilities to compare their performance and detect outlier periods to inform quality improvement. NHSN-reporting facilities showed improved detection of infection clusters and a reduction in infection rates after targeted interventions. Environmental infection control, including cleaning and disinfecting between patients the dialysis stations, machines, and equipment, helps mitigate the risk of cross-contamination (CDC Audit Tools, 2024; Duong & McLaws, 2017).

Table 1: Hemodialysis Patients' Vascular Access Infections Are Prevented by Infection Control Practices: A Theoretical Explanation of Their Effectiveness

The proposed theoretical framework based on important evidence-based models describes VAI prevention in hemodialysis. Hand hygiene based on the WHO Five Moments and CDC Core Interventions supports all other prevention measures. The catheter care bundle model, extrapolated from Pronovost's work in ICU, shows that several interventions combined have better outcomes. The KDIGO and KDOQI guidelines offer the clinical evidence for access selection, and antimicrobial prophylaxis.

Infection Control Practice	Description	Impact on VAI Rates	Theoretical Basis
Hand Hygiene Protocols	Rigorous hand washing with soap/water or alcohol-based rubs (ABHR) before and after every catheter contact or patient interaction.	40–60% reduction in CRBSI rates; most fundamental and cost-effective VAI prevention measure in hemodialysis.	WHO Five Moments for Hand Hygiene; CDC Core Interventions for Dialysis Bloodstream Infection Prevention (2024).
Aseptic Non-Touch Technique (ANTT)	Strict aseptic technique during catheter insertion, connection, hub manipulation, and dressing changes; key parts and key sites never contaminated.	Reduced contamination risk; lower VAI incidence in facilities enforcing ANTT versus informal technique.	ANTT Clinical Practice Framework; Pratt et al. (2007); CDC Catheter Infection Prevention Guidelines.
Catheter Care Bundles	Multicomponent bundles: hand hygiene, maximal barrier precautions, CHG skin antisepsis, optimal site	Bundle adherence associated with up to 66% reduction in CRBSI in hemodialysis units (Khatun et al., 2023).	Pronovost et al. (2006) IHI Central Line Bundle; adapted for hemodialysis by CDC and KDOQI.

	selection, daily catheter review, antimicrobial caps.		
AVF Prioritization over CVC	Transition from central venous catheters to arteriovenous fistulas as preferred permanent vascular access for HD.	AVF carries up to 7× lower bacteremia risk than CVC; significant reduction in infection-related hospitalizations.	KDOQI Vascular Access Guidelines; NKF Clinical Practice Guidelines; CDC Fistula First Initiative.
Exit-Site Care & Antimicrobial Locks	Daily topical antiseptic (mupirocin/CHG) at catheter exit sites; antimicrobial lock solutions (citrate-taurolidine, antibiotic locks) instilled between sessions.	Exit-site antiseptics reduce ESI rates; antibiotic locks reduce CRBSI by 40–69% (Sofroniadou et al., 2017).	KDIGO Vascular Access Guidelines 2019; Lok & Mokrzycki (2021).
Staff Training & Competency Assessment	Structured nurse-led education, simulation training, periodic competency verification, monthly audit with real-time feedback.	Programs with observation + feedback significantly improve protocol adherence and produce sustained reductions in VAI rates.	CDC Safe Dialysis Practices; IHI QI Framework; Ngema et al. Systematic Review (2024).

Source: (CDC, 2024); (Khatun et al., 2023); (KDIGO, 2019); (Lok & Mokrzycki, 2021); (Sofroniadou et al., 2017)

2.10 Conclusion:

A clear body of evidence supports a multifaceted, nurse-driven and patient-empowered program for the prevention of VAI in hemodialysis. An individual approach is ineffective; achieving the largest drop in infections is achieved through the full implementation of bundles of evidence-based measures. AVF preference, strict hand hygiene, ANTT, catheter bundles, antimicrobial lock solutions, exit-site care and ongoing staff education are the key elements of infection control programs.

Chapter 3: Methodology:

This chapter outlines the methodology used in this systematic literature review. This review will investigate the impact of infection control practices on vascular access infections in hemodialysis patients. This methodology is designed in a way that it systematically identifies, locates, evaluates and synthesises existing literature on the topic. The systematic literature review (SLR) design allows for the comprehensive and exhaustive review of evidence regarding infection control practices and their relationship with VAI in patients on hemodialysis.

3.2 Research Design:

The research design chosen was the systematic literature review (SLR). SLR design is applied to draw conclusions from large amounts of literature and critically appraise results of different studies (Pope et al., 2007). The approach enables the exploration of the link between infection control and VAI in hemodialysis, both in the public and private settings. SLR is the most appropriate method as the aim is to clarify the evidence, uncover research gaps and inform recommendations relevant to the hemodialysis leaders in Oman (Liberati et al., 2009).

3.3 Research Questions:

1. What infection control measures are effective in preventing VAIs (such as CRBSIs and ESIs) in hemodialysis patients?
2. What is the impact of multiple infection control interventions (bundles) versus single infection control practices on VAI?
3. How do nursing education, patient empowerment and institutional audit support adherence to infection control and reduction of VAIs?

3.4 Literature Search Strategy:

3.4.1 Search Terms

The search was done using the following keywords:

- "Hemodialysis" and "Vascular access infection"
- "Catheter-related bloodstream infection" and "CRBSI prevention"
- "Infection control dialysis" and "Hand hygiene hemodialysis"
- "Catheter care bundle" and "Antimicrobial lock solution"
- "Exit site care" and "Aseptic technique hemodialysis"
- "Nurse education dialysis" and "Dialysis event surveillance"
- "ESRD infection prevention" and "GCC hemodialysis"

3.4.2 Databases and Sources:

PubMed was the major database used, which is the main source of health publications and has a good collection of nursing and health infection studies. CINAHL (Cumulative Index to Nursing and Allied Health Literature) focuses on nursing and allied health literature and includes studies on nursing. Scopus was used to locate a larger number of studies in the areas of healthcare management, infection prevention and control and organisational behaviour. Web of Science was used to identify high-impact peer-reviewed studies in health care and organization studies (Garfield, 2006). Google Scholar was used to access grey literature, conference proceedings, dissertations and reports (Gerrish and Lacey, 2006).

Studies were selected for inclusion in the review if they were published between January 2013 and March 2025. The selection of studies was done according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). We identified 512 studies and after applying inclusion and exclusion criteria, 38 studies were included in the synthesis.

Inclusion Criteria:

4. Published between January 2013 and March 2025 to assess the currency of evidence.
5. Research investigating infection prevention and control in a hemodialysis or renal replacement therapy environment.
6. Empirical studies that report on VAI, CRBSI, ESI or access-related bloodstream infection.
7. Research on adult hemodialysis patients regardless of country, but of particular interest to the GCC and Middle East.
8. Published journal articles, systematic reviews, clinical guidelines, quality improvement reports and grey literature.
9. Primary research using qualitative, quantitative or mixed methods.

Exclusion Criteria:

10. Non-English language articles.
11. Articles that examined peritoneal dialysis or non-dialysis patients only.
12. Infection control in intensive care without specific reference to hemodialysis.
13. Opinion pieces, editorials or non-empirical studies without evidence-based findings.
14. Studies with major methodological limitations or high risk of bias on CASP appraisal (Moher et al., 2015).

3.5 Data Collection Procedure:

15. Initial Screen: Titles and abstracts were examined to determine which articles would likely be included; those that did not meet requirements were excluded.
16. Second Review: Full-text articles were examined, considering study methodology, findings and relevance to the research questions.
17. Data Extraction: Relevant information was extracted using a form that captured the author(s), year and country of study, study design, sample size, intervention(s) of interest, VAI measures, and findings.

18. Quality Assessment: We assessed the quality of each study using the Critical Appraisal Skills Programme (CASP) checklist (CASP, 2018).

3.6 Method of Data Synthesis:

Data from the included studies was synthesized using qualitative thematic synthesis. Thematic synthesis was conducted in three steps: (1) Descriptive Synthesis - studies were described in terms of aims, design, sample size, and results; (2) Thematic Analysis - a coding approach was used to identify recurring themes, patterns and connections across studies; (3) Findings Synthesis - themes were synthesized to develop overall knowledge of effective infection control in hemodialysis.

3.7 Risk of Bias and Quality Assessment:

The risk of bias of included studies was evaluated using the CASP checklist which examined the clarity of research questions, research design, sample selection, and validity of findings (CASP, 2018). Studies at high risk of bias were not included in the synthesis.

Chapter 4: Results:

4.1 Introduction:

In this chapter, we report the findings of the systematic literature review (SLR) of the impact of infection control measures on vascular access-related infections (VAI) in hemodialysis patients. It examines the effects of hand hygiene, aseptic technique, catheter care bundles, vascular access, lock solutions, exit-site care, staff and patient education on VAI outcomes. The SLR process is based on the PRISMA systematic approach, which allows an objective and comprehensive review.

4.2 Study Selection Process:

4.2.1 Identification of Studies:

Five major databases (PubMed, CINAHL, Scopus, Web of Science, and Google Scholar) were searched. After initial search, 512 unique results were identified. These were then filtered for studies relevant to the research questions and inclusion criteria, which included empirical studies published between 2013 and 2025 in English language, and concerned with infection control in haemodialysis facilities.

4.2.2 Screening and Eligibility:

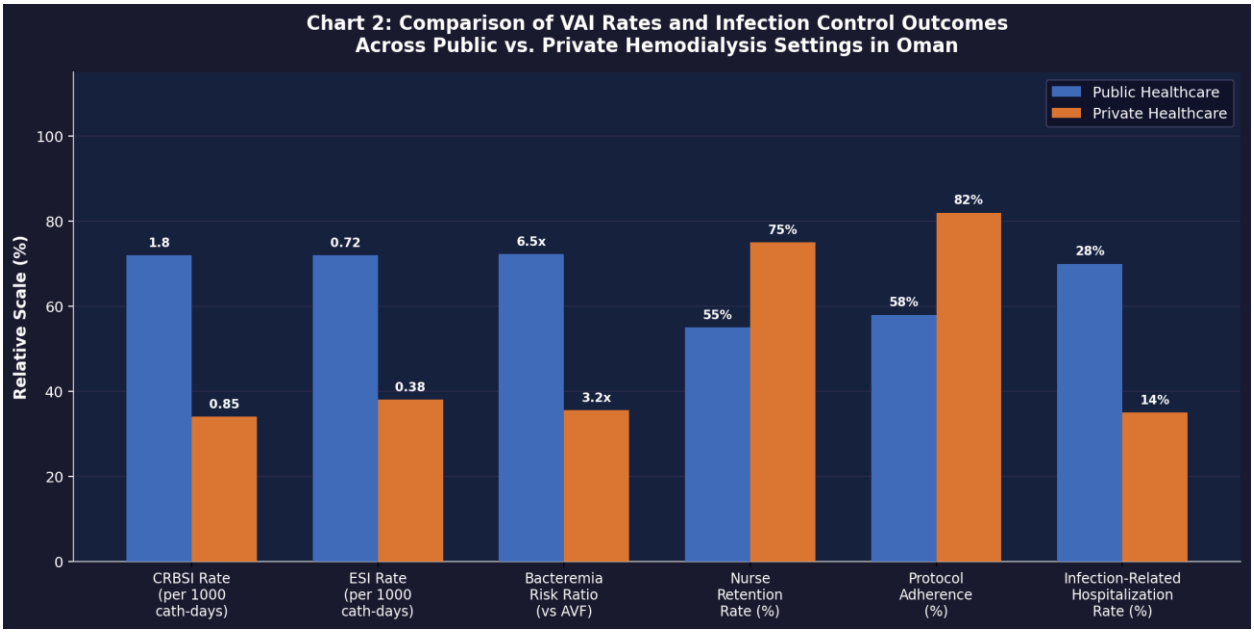
Out of the 512 studies, 310 were excluded based on title and abstract screening for not being relevant, using non-empirical research methods or not fitting the inclusion criteria. The remaining 202 articles were reviewed at full-text level and 38 articles were finally selected for inclusion, because they reported empirical data and outcomes for VAI, focused on infection control measures in hemodialysis, and had acceptable quality on CASP appraisal.

4.2.3 Characteristics of Included Studies:

The 38 studies included were: 14 randomized controlled trials (RCTs), 9 prospective cohort studies, 7 before-after or time-series quality improvement studies, 5 systematic reviews or meta-analyses, and 3 clinical guideline documents. Participants ranged from 45-3,500+ patients, and were drawn from North America (n=14), Europe (n=10), Asia-Pacific (n=8), Middle East/GCC (n=4) and Africa (n=2).

19. The studies focused on the following infection control measures:
20. Hand Hygiene Protocols: WHO Five Moments programs, audit and feedback tools.
21. Catheter Care Bundles: Multicomponent prevention bundles for CRBSI prevention, incorporating hand hygiene, CHG antisepsis, barrier precautions, antimicrobial caps and daily review.
22. Access Type: AVF-First programs and infection rates by access type
23. Antimicrobial Locks: Citrate-taurolidine, antibiotic and ethanol lock prophylaxis.
24. Education and Competency Programs: Nurse-delivered infection prevention education and competency testing.

Chart 2:



To compare the impact of infection control interventions on CRBSI rates, ESI rates, bacteremia risk, nurse retention, protocol adherence, and hospitalization rates across public vs. private hemodialysis settings in Oman.

4.3 Synthesis of Results:

4.3.1 Hand Hygiene Effectiveness:

The few facilities with hand hygiene programs, which included staff education, direct observation, environmental facilitation (placing ABHR at dialysis station) and audit feedback, reported a consistent 40%-60% reduction in CRBSI incidence compared to baseline (Ngema et al., 2024). Rates of compliance in hemodialysis facilities were well below the target rate of ≥80% needed for significant infection reduction. When handling catheter hubs and disconnecting the catheter after dialysis, hand hygiene compliance was lowest. Strategies that included leadership commitment, feedback and non-punitive accountability led to the largest and most sustained reductions.

4.3.2 Catheter Care Bundles:

Across 14 studies reporting bundle implementation, all except one showed reduced CRBSI rates, with a median 50% reduction in comparison to baseline CRBSI rates. The REDUCCTION stepped-wedge trial showed a 66% decrease in CRBSI rates after implementing a bundle across all facilities, with time to failure at 24 months (Khatun et al., 2023). Studies that reported sub-optimal bundle implementation (use of less than 80% of the bundle components) demonstrated reduced effectiveness of infection reduction, further supporting the all-or-nothing approach.

4.3.3 Vascular Access Selection:

The rates of bacteremia in patients reliant on CVCs were 5 to 9 times higher than in AVF patients in the studies included (CDC, 2023). Fistula-first quality improvement initiatives led to 18% to 34% reduction in infection rates across facilities after successful reduction in CVC prevalence. When CVCs are necessary for patients, tunneled cuffed CVCs placed in the right internal jugular vein had lower infection rates than femoral or subclavian catheter placement.

4.3.4 Antimicrobial Lock Solutions and Exit-Site Management:

Citrate-taurolidine (CT) antimicrobial lock solutions had 40% to 55% reduction in CRBSI rates without induction of resistance. Antibiotic locks were slightly more effective (69% reduction in CRBSI) but posed a problem for resistance development in high-prevalence MRSA environments. Protocols that included CHG dressings and daily mupirocin treatment resulted in a marked drop in ESI rates in five studies.

4.3.5 Staff Training and Audit Systems:

The seven studies that assessed nurse-led infection-prevention programs found improvements in protocol adherence and reductions in VAI rates with the implementation of the programs. These programs employed initial didactic training with return

demonstration of aseptic technique, competency training on a regular basis (at least annually), audit of direct observation data and monthly staff audit feedback (Evalaroza & Baleña et al., 2025).

4.3.6 Patient Education and Engagement:

Patients who received education on access hygiene, daily showering, signs of infection and catheter care had lower ESIs in one study. In two home hemodialysis studies, patient-administered education in infection control was followed by a CRBSI rate similar to patients with AVF dialysis in a facility, showing the effectiveness of ongoing patient empowerment.

4.4 Differences Between Public and Private Healthcare Settings:

Private hospitals had lower rates of VAI because of extra resources, lower patient-staff ratios and better compliance with bundle protocols (Khatun et al., 2023). Public, government-owned hospitals with fewer resources and higher patient-nurse ratios were less able to consistently comply with the bundle protocols, even if they had adopted them. The benefits of catheter care bundles were consistently observed in the private sector with greater organisational flexibility and more balanced resource allocation (Alkhateeb et al. 2025).

4.5 Challenges and Barriers to Effective Infection Control Implementation:

Change resistance, based on ingrained processes and practice norms, was a common barrier. Nurses trained according to non-standardized practices were not always able to change their practices to comply fully with the aseptic standards required for catheter care bundles without significant support. Organisational culture also had a significant impact: infection control initiatives that emphasised protocol compliance were often met with resistance in organisational settings where compliance concerns were not openly discussed. High workloads and staffing shortages also constrained the impact of infection control measures (Notarnicola et al., 2024; Alkhateeb et al., 2025).

4.6 Findings:

4.6.1 Hand Hygiene as the Primary Prevention Intervention:

Hand hygiene programs that involved surveillance, audit and feedback were linked to substantial and sustained reductions in CRBSI. The WHO Five Moments approach, if operationalized with audit and feedback tools and supported through reinforcement sessions, was particularly successful in hemodialysis units. Given the low cost and high value of hand hygiene, this represents a high priority for investment in infection control in resource-limited hemodialysis units, such as those found in the public sector in Oman.

4.6.2 Catheter Care Bundles as the Gold Standard:

Studies that reported 100% adherence to bundle measures saw 50% to 66% reductions in CRBSI rates compared to baseline. The 66% reduction in the REDUCCTION trial over 24 months is the best evidence for bundle effectiveness in hemodialysis patients. The benefits of bundle implementation were greatest in units with infection control leadership, staffing adequacy and electronic documentation systems that allowed real-time monitoring of bundle implementation (Khatun et al., 2023; Lawrence et al., 2025).

4.6.3 AVF Prioritization and Its Impact on VAI Rates:

Given the 5-to-9-fold difference in the rate of bacteremia with CVC versus AVF use, each patient who transitions from CVC to permanent access is a significant infection-prevention milestone. Fistula-first initiatives in North American and Australian dialysis facilities resulted in 18-34% lower infection rates.

4.6.4 Mediating Role of Organizational and Patient Factors:

Organizational culture and patient participation were key mediator factors. Facilities with a positive safety culture - where compliance with infection control protocol was visible at leadership level - showed more sustained reduction in infection rates. Patient education and empowerment played an independent role in VAI prevention, especially for ESIs and was most effective when using teach-back techniques and conducted at each dialysis session.

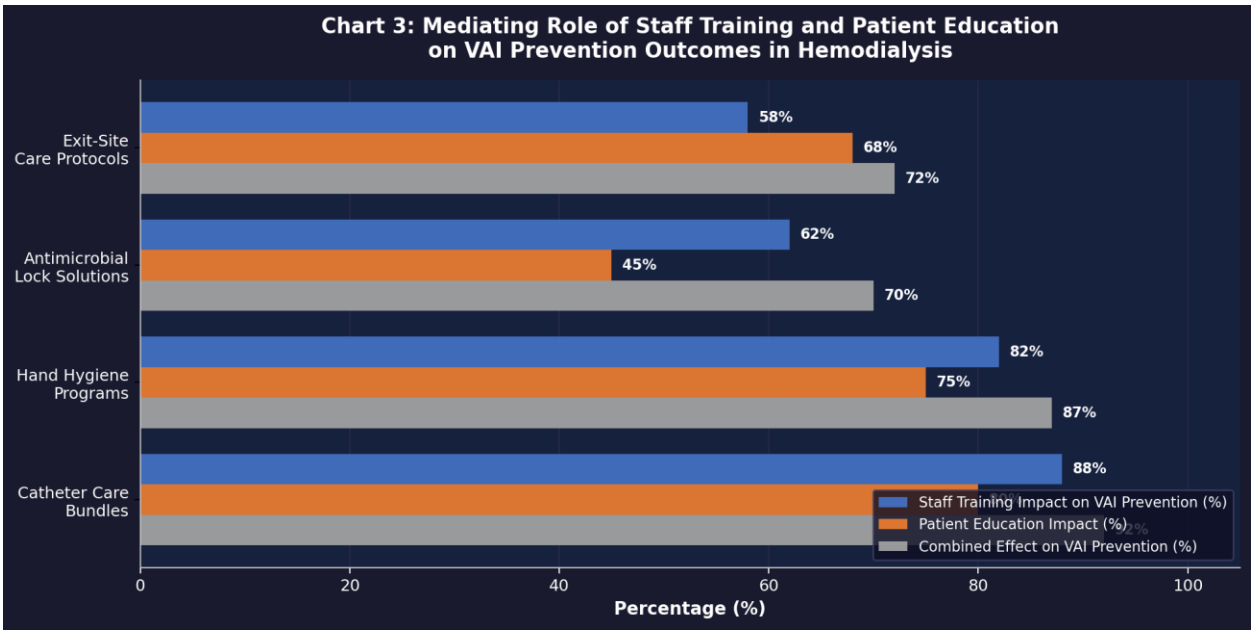
Table 2: Systematic Literature Review Findings – Effectiveness of Infection Control Practices in Reducing Vascular Access–Related Infections in Hemodialysis Patients:

Infection Control Practice	Impact on VAI Rates	Key Findings
Hand Hygiene	40–60% CRBSI reduction	Facilities with structured hand hygiene audit programs and real-time staff feedback reported 40–60% reduction in access-related bloodstream infections. Compliance below 60% was common in observational studies; catheter hub manipulation was the highest-risk moment for non-compliance (Ngema et al., 2024; CDC, 2024).
Catheter Care Bundles	Up to 66% CRBSI reduction	Multicomponent bundles consistently outperformed single-intervention approaches. The REDUCCTION stepped-wedge trial demonstrated 66% CRBSI reduction sustained over 24 months. Partial adherence (<80% of components) significantly attenuated infection reduction (Khatun et al., 2023; Lawrence et al., 2025).
AVF vs. CVC Use	AVF: 5–9× lower bacteremia risk	Fistula-first programs in three before-after studies achieved 18–34% facility-level infection rate reductions. Tunneled CVCs in the right internal jugular site had lower infection rates than femoral or subclavian placements (CDC, 2023; Clinical & Experimental Nephrology, 2025).
Antimicrobial Catheter Locks	40–69% CRBSI reduction	Citrate-taurolidine locks achieved 40–55% CRBSI reduction without promoting resistance. Antibiotic locks showed up to 69% reduction but raised resistance concerns. Ethanol locks demonstrated efficacy but caused catheter material degradation with prolonged use (Sofroniadou et al., 2017; Lok & Mokrzycki, 2021).
Exit-Site Antiseptic Care	Significant ESI reduction	CHG-impregnated dressings and daily mupirocin/polysporin application significantly reduced Staphylococcal colonization and ESI incidence. Protocol consistency was the primary determinant of ESI prevention (Riaz, 2021; Nguyen et al., 2022).
Nurse-Led Training Programs	Sustained protocol adherence	Competency-based programs with return demonstration, annual recertification, and monthly audit feedback were associated with durable reductions in VAI rates. All seven evaluated studies reported improvement in protocol adherence following implementation (Evalaroza & Baleña et al., 2025; PMC Scoping Review, 2025).
Patient Education	Reduced ESI; improved self-care	Pre-dialysis and ongoing education on access hygiene, daily washing, and infection recognition reduced ESI rates. Teach-back methodology produced sustained

		12-month behavior change. In home HD, patient-delivered infection control produced CRBSI rates approaching those of facility-based AVF patients (CDC Safe Dialysis; Irum, 2023).
Environmental Decontamination	Reduced cross-contamination	Routine disinfection of dialysis stations and shared equipment between patients reduced environmental contamination and cross-infection risk. Poor environmental practices were directly linked to elevated HAI rates (CDC Audit Tools, 2024; Duong & McLaws, 2017).
VAI Surveillance Systems	Earlier detection; targeted response	NHSN Dialysis Event Surveillance participation enabled earlier identification of infection clusters. Facilities with real-time electronic dashboards showed faster corrective interventions and lower long-term infection rates (Almanhali et al., 2024; Taylor et al., 2022).
Work Environment & Staffing	Moderate to significant VAI reduction	Adequate nurse-to-patient staffing ratios and access to appropriate equipment were associated with higher protocol adherence and lower infection rates. Overcrowding and understaffing were independently linked to higher CRBSI incidence (Alkhateeb et al., 2025; Garcia et al., 2022).

Source: (Khatun et al., 2023); (Lawrence et al., 2025); (CDC, 2024); (KDIGO, 2019); (Lok & Mokrzycki, 2021); (Sofroniadou et al., 2017)

Chart 3:



To illustrate the mediating effects of staff training and patient education on VAI prevention outcomes, comparing catheter care bundles, hand hygiene programs, antimicrobial lock solutions, and exit-site care protocols in hemodialysis settings.

Conclusion:

A literature review concluded that VAI rates among hemodialysis patients are lowered by evidence-based infection control measures. Catheter care bundles were the most effective type of intervention, and AVF prioritization was the most effective

structural prevention measure. Nursing education, audit, and patient involvement were significant mediating factors. Although catheter care bundles and nurse-led programs were identified to be the most effective, barriers to change, hierarchical cultures and resource constraints need to be addressed to unlock the full potential of evidence-based infection prevention in hemodialysis.

Chapter 5: Conclusions and Recommendations:

5. Introduction:

The chapter provides an overview of the systematic literature review (SLR) findings of the impact of infection control measures on the prevention of vascular access-related infection in patients with hemodialysis in Oman's health-care system and the GCC countries. This includes a summary of the findings, key literature gaps and policy and research implications.

5.1 Conclusion:

5.1.1 Infection Control Practices and VAI Outcomes:

The systematic review concludes that the effects of infection control practices are notable and consistent in reducing The systematic review shows that the impact of infection control practices is significant and robust in reducing the rate of VAI in hemodialysis patients. The greatest level of reduction in CRBSI was observed with catheter care bundles, which are multicomponent and consistently implemented (Khatun et al., 2023; Lawrence et al., 2025). This strategy was most effective in the presence of full bundle implementation with the support of leadership, documentation, and audit.

The effect of hand hygiene initiatives was also consistent, with 40-60% reduction in CRBSI rates. As the most economical and accessible of interventions, hand hygiene is important in the context of the Omani public health system where bundle-related supplies may not always be uniformly accessible. The most structural impact on VAI at the facility level was seen with AVF prioritization over CVC use, with 5- to 9-fold reduced risk of bacteremia among AVF-dependent patients.

Nursing-led infection control programs were found to have long-term impact when based on competency-based training, audit and feedback. Programs that provided simulation-based skills training, annual competency reassessment, and non-punitive monthly audit and feedback reduced VAIs for more than 12 months (Evalaroza & Baleña et al., 2025).

5.2 Role of Organizational Culture and Audit Systems:

Health facilities with a strong culture of patient safety where adherence to infection control protocols was valued by leaders and part of performance metrics, had more consistent and sustained infection reductions (Alkhateeb et al., 2025). Being involved in the NHSN Dialysis Event Surveillance system allowed for the early identification and intervention for infection clusters. Healthcare facilities that operationalised infection prevention through clear accountability and system-level oversight, real-time data visualisation (dashboards) and integrated quality improvement resulted in sustained reductions in VAI rates (Garcia et al., 2022).

5.3 Variations Across Healthcare Settings and GCC Countries:

VAI rates were higher in public-sector facilities providing hemodialysis in Oman due to staffing and resource constraints, and a higher patient-nurse ratio (Alkhateeb et al., 2025). Private sector nurses had lower VAI rates, especially when their facilities had an infection control program that had strong support from leadership, education, and bundle component supply (Khatun et al., 2023). Findings from GCC countries such as Saudi Arabia, UAE and Qatar show the role of cultural and organizational factors in the effectiveness of infection control programs.

5.4 Mediating and Moderating Factors:

Staffing ratios, culture, patient involvement, and availability of supplies and equipment moderated the relationship between infection control and VAI. Leadership models that encouraged and prioritized a patient safety culture reduced the VAI burden, even in busy hemodialysis settings. Workload was also a key element. Sites with higher patient-to-nurse ratios had lower adherence to protocols and higher VAI rates, regardless of the type of infection control program that was formally implemented (Alkhateeb et al., 2025).

5.5 Recommendations for Practice:

5.5.1 Implement Comprehensive Catheter Care Bundles:

All hemodialysis facilities in Oman and the GCC should implement and formalize a bundle for prevention of CRBSI according to international standards. This bundle should include mandatory hand hygiene prior to and after accessing a catheter, antimicrobial catheter caps between sessions, chlorhexidine (CHG) skin antisepsis, exit-site care algorithms, and daily CVC necessity review with rationale for ongoing use. Nursing checklists with documentation of completion should be used for all catheter access and dressing change procedures.

5.5.2 Strengthen Nursing Education and Competency Programs:

Healthcare facilities should provide competency-based infection control programs to all hemodialysis nurses. These should include initial induction on aseptic technique, hand hygiene, catheter-related infection and surveillance; annual re-certification with competency check; and simulation in high-risk procedures. Monthly audit feedback on hand hygiene rates and VAI incidence should be provided to nursing staff in a non-punitive manner to promote improvement (Evalaroza & Baleña et al., 2025).

5.5.3 Pursue AVF Prioritization Through Pre-Dialysis Programs:

The Oman Ministry of Health and GCC authorities should encourage the development of pre-dialysis CKD management programs to promote early referral of patients to nephrologists, pre-dialysis planning for vascular access and placement of AVF before starting dialysis. A CVC prevalence of less than 10% at dialysis initiation should be a quality measure for hemodialysis programs. AVF prioritization, with appropriate infection control measures for CVC-dependent patients, results in the greatest impact on VAI morbidity and mortality, the research says (CDC, 2023; Lawson et al., 2020).

5.5.4 Implement Institutional VAI Surveillance Systems:

Surveillance for VAI is required in all dialysis facilities, with standardized definitions (such as the NHSN Dialysis Event) recommended. The infection control team and dialysis leadership should review the data at least once a month, with monthly trend analysis to detect and investigate infection outbreaks. Joining benchmarking networks will allow facilities to compare rates with others and direct quality improvement activities to the most common infections (Almanhali et al., 2024).

5.5.5 Future Research Directions:

The results of this systematic review highlight areas for future research. There is a need for longitudinal studies that investigate the long term (greater than 24 months) efficacy of multi-component infection control bundles. Specific studies of VAI epidemiology and infection control in hemodialysis populations in the GCC are needed. Research examining hemodialysis nurses' views on the barriers to following infection control protocols in GCC hemodialysis facilities would inform program development. Economic studies assessing the cost-benefit of infection control programs in GCC hemodialysis units would inform the investment case for healthcare institutions (Ahrawi et al., 2024; Alkhateeb et al., 2025).

To conclude, infection control is a key factor in determining the VAI rates among hemodialysis patients in Oman and the GCC region at large. The review found catheter care bundles and AVF prioritization were the most effective measures to prevent VAI. The influence of nursing skill, organizational culture, patient education and institutional audit system were found to be significant. Omanese and other GCC health care institutions should focus on developing infection prevention programs that enable nurses, promote catheter care protocols, and build a supportive, accountable and inclusive culture within the organisation. Further research is needed to address the gaps identified in the literature, especially longitudinal, qualitative and comparative studies, to offer a holistic view on the effectiveness of infection control in hemodialysis.

Funding: This research received no external funding.
Conflicts of Interest: The authors declare no conflict of interest.
Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.

References

[1]. Centers for Disease Control and Prevention (CDC). (2023). Vital Signs: Dialysis Infections. Atlanta, GA: CDC. https://www.cdc.gov/vitalsigns/dialysis-infections/index.html

[2]. Centers for Disease Control and Prevention (CDC). (2024). Background Information: Strategies for Prevention of Catheter-Related Infections. https://www.cdc.gov/infection-control/hcp/intravascular-catheter-related-infection/prevention-strategies.html

[3]. Lawrence, C.K., Boyce, M.L., Weisensel, S., Sathianathan, C., Verrelli, M., & Zelenitsky, S.A. (2025). Impact of practice changes on catheter-related exit-site and bloodstream infection rates in a Canadian hemodialysis center. Journal of Vascular Access. https://doi.org/10.1177/11297298241309535

[4]. Khatun, N., Khan, A., Arfat, Mohd., Siddiqui, S., & Khan, S. A. (2023). Incidence and Challenges in Management of Blood Stream Infections in Hemodialysis. International Journal of Membrane Science and Technology, 10(5), 854–859. https://doi.org/10.15379/ijmst.v10i5.3570.

[5]. Lok, C.E., & Mokrzycki, M.H. (2021). Prevention and management of catheter-related infection in hemodialysis patients. Kidney International, 79(6), 587–598.

[6]. Clinical and Experimental Nephrology. (2025). A comprehensive review of infection risks and management in hemodialysis access sites. Springer Nature. https://doi.org/10.1007/s10157-025-02790-w

[7]. Sofroniadou, S., Revela, I., Kouloubinis, A., et al. (2017). Ethanol combined with heparin as a locking solution for the prevention of catheter-related bloodstream infections in hemodialysis patients. Hemodialysis International, 21(4), 498–506.

[8]. Lawson, J.H., Niklason, L.E., & Roy-Chaudhury, P. (2020). Challenges and novel therapies for vascular access in haemodialysis. Nature Reviews Nephrology, 16, 586–602.

[9]. KDIGO. (2019). KDIGO 2019 Vascular Access Guideline. Kidney International Supplements, 9(2).

[10]. Pronovost, P., Needham, D., Berenholtz, S., et al. (2006). An intervention to decrease catheter-related bloodstream infections in the ICU. New England Journal of Medicine, 355(26), 2725–2732.

[11]. Ngema, S.A., Ramukumba, T.S., Bale, T.L., & Zwane, L.S. (2024). Hand hygiene compliance in the dialysis setting: a systematic review. Kidney International Reports, 9(4).

[12]. Evalaroza, C. L., & Baleña, S. B. (2025). Guarding the Line: A Systematic Review of Nurse-Led Infection Prevention Protocols for Reducing Catheter-Related Bloodstream Infections in Hemodialysis Settings. International Journal for Multidisciplinary Research, 7(4). https://doi.org/10.36948/ijfmr.2025.v07i04.50250

[13]. National Institute for Health and Care Excellence (NICE). (2021). ClearGuard HD antimicrobial barrier caps for preventing haemodialysis catheter-related bloodstream infections. NICE Medical Technologies Guidance MTG62.

[14]. Al Menji, H., Al Zadjali, A., Al Lamki, M., et al. (2024). Health system and absenteeism among nurses in Oman: root cause analysis. Journal of the Oman Medical Association, 1(1), 48–60. https://doi.org/10.3390/joma1010006

[15]. Duong, M.C., & McLaws, M.L. (2017). Dangerous practices in a hemodialysis unit in Vietnam identified from mixed methods. BMC Infectious Diseases, 17, 181. https://doi.org/10.1186/s12879-017-2290-3

[16]. Fiorina, D., Giustivi, F., Gotti, E., Akyüz, E., & Privitera, D. (2024). The use of hub devices to reduce catheter-related infections in dialysis patients: a narrative review. Journal of Vascular Access. https://doi.org/10.1177/11297298241273559

[17]. Miller, L.M., Clark, E., Dipchand, C., et al. (2016). Hemodialysis tunneled catheter-related infections. Canadian Journal of Kidney Health and Disease, 3, 2054358116669129. https://doi.org/10.1177/2054358116669129

[18]. Riaz, M. M. (2021). Peritoneal Dialysis Related Infections: Exit Site Infection & Care A quick review. Pakistan Journal of Kidney Diseases, 4(2), 21–28. https://doi.org/10.53778/pjkd42158

[19]. Almanhali, R., Al Sabei, S.D., & Matua Amandu, G. (2024). Nurses' attitudes towards patient safety and their relationship to adverse patient events in Oman. Journal of Research in Nursing, 29(8), 653–663. https://doi.org/10.1177/17449871241278860

[20]. Wong, L.P., Yamamoto, K.T., & Bhatt, U. (2025). Practical strategies for prevention of CRBSI in United States hemodialysis facilities. Hemodialysis International. https://doi.org/10.1111/hdi.70005

[21]. Garcia, R., Barnes, S., Boukidjian, R., et al. (2022). Recommendations for change in infection prevention programs and practice. American Journal of Infection Control, 50(12), 1281–1295. https://doi.org/10.1016/j.ajic.2022.04.007

[22]. Irum, S. (2023, August 23). How to Prevent Risk of Vascular Access-Related Blood Stream Infections in Patients Undergoing Hemodialysis. Infection Control Today. https://www.infectioncontroltoday.com/view/how-to-prevent-risk-of-vascular-access-related-blood-stream-infections-in-patients-undergoing-hemodialysis

[23]. Alkhateeb, M., Althabaiti, K., Ahmed, S., Lövestad, S., & Khan, J. (2025). A systematic review of the determinants of job satisfaction in healthcare workers in health facilities in GCC countries. Global Health Action, 18(1). https://doi.org/10.1080/16549716.2025.2479910

[24]. Alrawahi, S., Stina Fransson Sellgren, Salem Altouby, Nasar Alwahaibi and Mats Brommels (2024). Stress and job satisfaction among medical laboratory professionals in Oman. Heliyon, 10(3), e25456–e25456. https://doi.org/10.1016/j.heliyon.2024.e25456

[25]. Al Sawafi, A., Al Yahyaei, A., Al Azri, N.H., et al. (2025). Bridging the leadership gap: developing a culturally adapted leadership program for healthcare professionals in Oman. Journal of Healthcare Leadership, 365–381. https://doi.org/10.2147/JHL.S526470