Guarding the Line: A Systematic Review of Nurse-Led Infection Prevention Protocols for Reducing Catheter-Related Bloodstream Infections in Hemodialysis Settings

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Abstract

Background: Catheter-related bloodstream Infections (CRBSIs) are a significant cause of morbidity and mortality among patients undergoing hemodialysis via central venous catheters (CVCs). As frontline caregivers, nurses are uniquely positioned to lead infection prevention efforts. This systematic review aimed to evaluate the effectiveness of nurse-led infection prevention protocols in reducing CRBSIs in hemodialysis settings.

Methods: A comprehensive literature search was conducted across ScienceDirect, Google Scholar, ProQuest, and EBSCO, yielding 572 studies. Following title and abstract screening, full-text review, and critical appraisal using the CONSORT checklist, eight studies met the inclusion criteria. These studies included randomized controlled trials, quality improvement projects, and cohort designs published between 2013 and 2024. Data were synthesized using a narrative and thematic approach, with analysis structured around the Health Promotion Model (HPM) and the Donabedian Model of Quality of Care.

Results: Three major themes emerged: (1) structured protocol and care bundles, (2) quality improvement and cyclical strategies, and (3) behavior-focused educational interventions. Most studies reported significant reductions in CRBSI rates following the implementation of nurse-led protocols. Interventions that were standardized, well-monitored, and behaviorally reinforced proved most effective. Theoretical integration highlighted how successful interventions relied on individual behavioral change and systemic support structures.

Conclusion: Nurse-led infection prevention protocols are effective strategies for reducing CRBSIs in hemodialysis settings. Their success is amplified when guided by evidence-based practices, structured implementation, continuous quality improvement, and education. The dual application of the HPM and Donabedian Model underscores the need to align behavior change with supportive systems to enhance patient safety and healthcare quality.

Keywords: Catheter-related Bloodstream Infections, CRBSI, Hemodialysis, Nurse-led Interventions, Infection Prevention, Quality Improvement, Health Promotion Model, Donabedian Model

Introduction

Background of the Study

Catheter-Related Bloodstream Infections (CRBIs) are a significant source of morbidity and mortality in patients undergoing hemodialysis, primarily due to the invasive nature of procedures and dependence on central venous catheters (CVCs). These infections occur when microorganisms, including bacteria and fungi, colonize catheter surfaces and invade the bloodstream, often facilitated by biofilm formation, which provides a protective environment for pathogens and increases resistance to antimicrobial treatments.[1] Hemodialysis patients are particularly vulnerable to CRBSIs because repeated vascular access and prolonged catheter usage heighten their exposure to potential infection sources.[2] Furthermore, underlying comorbidities, such as diabetes and cardiovascular diseases, exacerbate their susceptibility by impairing immune responses.[3] The frequent handling of catheters during dialysis sessions also contributes to contamination risks, especially when there is variability in adherence to infection prevention protocols.[4] Despite advancements in antimicrobial catheters and aseptic techniques, CRBSIs remain a persistent problem, leading to extended hospital stays, increased healthcare costs, and higher mortality rates.[5] The impact on patients extends beyond physical health, as CRBSIs often require systemic antibiotic treatments, catheter replacements, and, in severe cases, intensive care management, which can be emotionally and financially burdensome.[6]

Preventing CRBSIs in hemodialysis settings remains a formidable challenge. Contributing factors include biofilm formation on catheter surfaces, inconsistent adherence to infection prevention protocols, and resource limitations in healthcare settings.[1,5] Nurse-led interventions have shown promise in addressing these challenges by improving compliance with infection prevention measures, reducing catheter dwell time, and enhancing patient education.[7,8]

Effective infection prevention strategies often incorporate bundles of care targeting central line-associated bloodstream infections (CLABSI), central venous catheters (CVC), and central venous access devices (CVAD). These bundles include standardized protocols for catheter insertion, maintenance, and removal, which have significantly reduce infection rates.[9] Procedural techniques such as proper dressing changes, flushing protocols, and meticulous handling practices also play a critical role in minimizing contamination and ensuring patient safety.[10] Nurse-led initiatives focusing on these areas enhance adherence to best practices.

Several studies have evaluated the effectiveness of nurse-driven protocols and multifaceted interventions in reducing catheter-related infections. For instance, Kotwal et al. (2022) demonstrated that a multidimensional intervention significantly reduced CRBSI rates in hemodialysis patients through the REDUCCTION trial, emphasizing the importance of collaborative approaches.[11] Similarly, Lucchini et al. (2024) highlighted the success of a nurse-led catheter bundle in minimizing CRBSIs in a retrospective cohort study. These interventions often combine education, consistent protocol enforcement, and regular auditing to achieve sustained results.[6] Despite these advances, gaps remain in synthesizing the findings from these individual studies. The inclusion of procedural techniques and bundles of care specific to CVCs and CVADs within systematic reviews can further strengthen the evidence base.

The limited number of systematic reviews addressing this issue underscores the need for further research to consolidate the evidence and identify best practices. This systematic review aims to synthesize existing literature on nurse-led infection prevention protocols for reducing CRBSIs in hemodialysis settings. Examining bundles of care, procedural techniques, and nurse-driven strategies aims to provide a

comprehensive understanding of the effectiveness of these interventions, identify successful strategies, and inform future research and practice.

Literature Review

Patients Undergoing Hemodialysis Utilizing Central Venous Catheters (CVCs)

Patients undergoing hemodialysis who rely on central venous catheters (CVCs) for vascular access are at a significantly heightened risk of catheter-related bloodstream infections (CRBSIs). The use of CVCs creates a direct pathway for pathogens to enter the bloodstream, presenting a significant–vulnerability. This risk is further exacerbated by biofilm formation on the catheter surfaces. Biofilms, which serve as protective environments for microorganisms, promote microbial growth and confer resistance to antimicrobial treatments, making infections more challenging to treat.[1] These challenges underscore the critical need for effective prevention measures tailored to patients requiring long-term catheter use.

Comparative studies have demonstrated that CVCs carry a much higher risk of infection than alternative vascular access methods, such as arteriovenous fistulas or grafts. The increased infection rates associated with CVCs highlight the importance of minimizing their usage whenever possible and implementing rigorous infection prevention protocols when their use is unavoidable.[2,5] Transitioning patients to safer vascular access options, such as fistulas, has been consistently recommended as a priority intervention in infection prevention strategies.

Recent research sheds further light on the factors contributing to CRBSI risk and potential interventions to mitigate this problem. A study by Weldetensae et al. (2023) conducted among 353 patients in a tertiary care hospital in Ethiopia found an alarming incidence rate of 7.74 CRBSI episodes per 1,000 catheter days. The study identified gram-negative bacteria as the predominant causative organisms and highlighted several risk factors for infection. Prolonged catheter duration, a history of previous CVC infection, low hemoglobin levels, and high white blood cell counts were all identified as significant contributors to CRBSI susceptibility. These findings underline the critical need for early and proactive management, including transitioning patients to arteriovenous fistulas to reduce dependence on temporary CVCs.[12]

In addition to the risks posed by prolonged catheter use, adherence to infection prevention protocols has been shown to play a decisive role in reducing CRBSIs. Shadle et al. (2022) emphasized the importance of consistent adherence to evidence-based protocols, including aseptic techniques and regular catheter maintenance, to mitigate infection risks. The study further highlighted the role of early intervention in reducing the burden of infections.[5] Similarly, Yang et al. (2021) underscored the effectiveness of quality improvement programs in addressing CRBSIs. Nurse-led initiatives, including targeted training and regular audits, were identified as key strategies for improving compliance with infection prevention measures and achieving sustained reductions in infection rates.[2]

These findings collectively emphasize the multifaceted nature of CRBSI prevention. While reducing dependence on CVCs through early transition to arteriovenous fistulas is a critical component, adherence to stringent infection prevention protocols and implementing quality improvement programs are equally vital. The role of healthcare providers, particularly nurses, in driving these preventive measures highlights the importance of a collaborative, multidisciplinary approach to infection control in hemodialysis settings.

Nurse-Led Infection Prevention Protocols

Nurse-led protocols have emerged as critical interventions to reduce catheter-related bloodstream infections (CRBSIs) in hemodialysis settings. These protocols are designed to standardize care and reduce practice variability, often incorporating hygiene training, antiseptic dressings, and catheter care bundles.

Such interventions focus on key infection prevention measures and have shown considerable promise in mitigating risks. For instance, Lucchini et al. (2024)[6] conducted a retrospective cohort study that demonstrated significant reductions in CRBSI rates following the implementation of a nurse-led catheter care bundle. The findings highlight the pivotal role of nurses in spearheading efforts to improve patient outcomes through the consistent application of evidence-based practices.

Hygiene-focused interventions form the cornerstone of nurse-led protocols, addressing critical factors such as handwashing and the use of antiseptic solutions. Giles et al. (2019)[13] emphasized that adherence to these measures can substantially improve compliance and reduce contamination risks. Similarly, Yang et al. (2021)[2] reported the effectiveness of quality improvement programs prioritizing nurse training and regular audits. These programs enhance adherence to infection prevention protocols and also foster a culture of accountability among healthcare workers. Despite these successes, challenges such as resource limitations and staff resistance can undermine the consistent application of such interventions (Wooten et al., 2022).[14]

To further support infection prevention efforts, the Centers for Disease Control and Prevention (CDC, 2024)[4] has issued core interventions aimed at reducing bloodstream infections in dialysis settings. These recommendations include routine staff education on infection control practices, strict adherence to hand hygiene protocols, proper catheter site care, and regular surveillance for infections. The CDC emphasizes that consistently implementing these measures can lead to substantial reductions in CRBSI rates. Similarly, the World Health Organization (WHO, 2024)[15] provides guidelines that underscore the importance of healthcare worker training in managing intravascular catheters, particularly in catheter insertion, maintenance, and removal. These global frameworks serve as essential references for developing nurse-led infection prevention programs.

However, the adoption of nurse-led protocols is not without its challenges. Wooten et al. (2022)[14] identified several barriers that hinder the consistent application of best practices for CRBI reduction in hemodialysis settings. Organizational resistance to change, financial constraints, and cultural factors often pose significant obstacles. For example, resource limitations may prevent facilities from providing adequate staffing or necessary supplies, while resistance from staff may stem from a lack of engagement or understanding of protocol benefits. Addressing these challenges requires a collaborative approach that involves leadership support, effective communication, and a commitment to standardization. The study by Wooten et al. (2022)[14] advocates for increased investment in education and training, coupled with strategic leadership initiatives to foster a supportive environment for protocol implementation.

Standard Infection Control Practices

Standard care practices are foundational in preventing catheter-related bloodstream infections (CRBSIs) in hemodialysis settings. These include sterile barriers during catheter insertion, routine dressing changes, and adherence to aseptic techniques. Thorne and Radford (2021)[9] emphasized the role of standardized care bundles in reducing infection rates by ensuring consistency in best practices. Similarly, meticulous catheter care protocols, such as those implemented in Shenzhen, China, achieved exceptionally low infection rates of 0.0229 per 1,000 catheter days over five years, underscoring the importance of sustained and rigorously applied care standards.[16]

Alternative approaches to CRBSI prevention have focused on innovations like antimicrobial-coated catheters, prophylactic antibiotic locks, and targeted preventive nursing. Antimicrobial lock solutions, including taurolidine and ethanol-based locks, have shown promise in reducing CRBSI incidence but face challenges such as potential antibiotic resistance and feasibility in resource-limited settings.[17,3] Cochrane

reviews suggest that while systemic antibiotics combined with lock solutions or guidewire catheter exchanges can be effective, their relative benefits and risks, such as catheter-associated venous stenosis or resistance, remain inconclusive.[17]

The Centers for Disease Control and Prevention's (CDC) Core Interventions remain a gold standard for CRBSI prevention, emphasizing regular staff training, proper catheter care, and infection surveillance. Fisher et al. (2020)[18] highlighted that gaps in adherence to these guidelines contribute to persistently high infection rates, necessitating novel therapies and stricter compliance monitoring. Additionally, Wooten et al. (2022)[14] highlighted systemic barriers, including organizational resistance and insufficient staffing, as significant obstacles to implementing best practices consistently. To overcome these challenges, they advocated for institutional reforms, including leadership support and enhanced staffing.

Recent advancements in preventive nursing have further improved outcomes. He et al. (2024)[19] demonstrated that targeted preventive nursing significantly reduced CRBSI rates, shortened catheter retention times, and improved patient quality of life compared to conventional care. This approach also alleviated patient stress and elevated nursing quality scores, highlighting the holistic benefits of integrating enhanced nursing care into infection prevention protocols.

In summary, while standard care practices and alternative infection prevention methods independently contribute to CRBSI reduction, their combined implementation, supported by robust institutional frameworks and innovative approaches, ensures the most effective outcomes in hemodialysis settings.

The primary objective of infection prevention initiatives in hemodialysis settings is to reduce catheter-related bloodstream infections (CRBSIs), enhance nursing practices, and improve patient safety. Multifaceted interventions have significantly decrease infection rates and bolster adherence to care protocols among healthcare staff. For instance, Kotwal et al. (2022)[3] reported that implementing a comprehensive intervention substantially reduced CRBSI rates, accompanied by improved compliance with infection control measures among nursing staff.)

Similarly, Lucchini et al. (2024)[6] found that introducing nurse-led catheter care bundles not only decreased infection incidences but also enhanced nurses' confidence and competence in infection prevention strategies. This aligns with the findings of Thorne and Radford (2021)[9], who concluded that bundle-based interventions effectively balance patient safety and infection control across diverse clinical environments. Improved nursing practices, such as meticulous documentation and routine audits, have also contributed to sustained reductions in CRBSI rates. Yang et al. (2021)[2] demonstrated that quality improvement programs focusing on nurse training and regular performance evaluations significantly declined central venous catheter-related infections. Furthermore, Wooten et al. (2022)[14] emphasized that addressing systemic barriers, including organizational resistance and insufficient staffing, is crucial for the consistent application of best practices in infection prevention.

In addition to these interventions, the establishment of dedicated nursing teams to assist with catheter insertions has been associated in reducing bloodstream infections. A study published in the American Journal of Infection Control reported that implementing a specialized team of nurses during central line insertions reduced the proportion of central line-associated bloodstream infections within seven days of line placement by 47% among patients included in the program.[20]

These studies underscore the critical role of nurse-led interventions and comprehensive infection prevention strategies in reducing CRBSI rates, enhancing nursing practices, and promoting patient safety in hemodialysis settings.

The body of research reviewed underscores the multifaceted nature of addressing catheter-related bloodstream infections (CRBSIs) in hemodialysis settings. While essential for vascular access, central venous catheters (CVCs), significantly increase the risk of infections due to factors such as biofilm formation, prolonged catheter use, and patient comorbidities. Targeted prevention strategies, including early transitions to arteriovenous fistulas, have been shown to mitigate these risks.[12,2]

Nurse-led interventions have become a cornerstone of infection prevention, incorporating hygiene training, catheter care bundles, and adherence to evidence-based practices. These interventions reduce CRBSI rates but also enhance the competence and confidence of nursing staff, as demonstrated by Lucchini et al. (2024) and Thorne and Radford (2021)[6,9]. Moreover, quality improvement programs focusing on regular training and performance audits further reinforce these outcomes, creating a culture of safety and accountability.[2]

Standard care practices, including sterile barrier techniques and routine catheter maintenance, remain indispensable in CRBSI prevention. Innovative approaches, such as antimicrobial-coated catheters and antibiotic lock solutions, provide additional layers of protection, although challenges such as cost, resistance development, and feasibility in resource-limited settings persist.[17,11] These methods are most effective when integrated with robust institutional frameworks, leadership support, and dedicated nursing teams, as highlighted by Wooten et al. (2022)[14] and APIC (2023).[20]

The synthesis of findings highlights that the most effective strategies for CRBSI prevention involve a combination of standard care practices, nurse-led protocols, and innovative interventions supported by institutional commitment. Addressing systemic barriers such as staffing shortages, organizational resistance, and resource constraints is essential to achieving sustained patient safety and infection control improvements. Collectively, these approaches emphasize the critical role of multidisciplinary collaboration in enhancing outcomes for hemodialysis patients.

Theoretical Framework

This study is grounded in two complementary theoretical foundations: Nola Pender's Health Promotion Model (HPM) and the Donabedian Model of Quality of Care. Together, these frameworks provide a robust foundation for examining nurse-led interventions and infection prevention strategies in hemodialysis settings.

Health Promotion Model (HPM) by Nola Pender

The Health Promotion Model emphasizes the proactive engagement of individuals in maintaining and enhancing health through behavior change and environmental management. Pender's framework highlights the importance of personal beliefs, perceived barriers, and self-efficacy in influencing health-promoting behaviors. In the context of this study, the HPM provides a lens for understanding how nurse-led interventions, such as hygiene training and catheter care bundles, empower healthcare professionals and patients to adopt infection prevention practices. The model underscores the role of nursing staff in fostering a supportive environment that motivates compliance with evidence-based practices to reduce catheter-related bloodstream infections (CRBSIs).

Donabedian Model of Quality of Care

The Donabedian Model evaluates healthcare quality through three interconnected components: structure, process, and outcomes. This model is particularly relevant to the study's focus on assessing the effectiveness of infection prevention interventions.

1. Structure refers to the organizational context in which care is delivered, including staffing levels, availability of infection prevention resources, and institutional support for nurse-led initiatives.
2. Process encompasses the actions taken to deliver care, such as adherence to aseptic techniques, implementing catheter care protocols, and regular performance audits.
3. Outcomes focus on measurable improvements in patient safety, such as reduced CRBSI rates and enhanced nursing competency.

In applying the Donabedian Model, this study aims to analyze how the structure and processes of nurse-led interventions contribute to favorable outcomes, thereby highlighting areas for continuous quality improvement.

Integrating the Health Promotion Model and the Donabedian Model provides a comprehensive approach to understanding the multifaceted aspects of infection prevention in hemodialysis settings. While the HPM focuses on individual and team behavior change to promote health, the Donabedian Model emphasizes the systemic factors that ensure the quality and safety of care delivery. Together, these frameworks guide the exploration of both personal and institutional factors influencing the success of nurse-led interventions, offering a holistic perspective on improving patient outcomes and fostering a culture of safety in healthcare environments.

Statement of the Problem

This study aimed to address this review question:

How effective are nurse-led infection prevention protocols in patients undergoing hemodialysis with central venous catheters, compared to standard care, in reducing catheter-related bloodstream infections and improving patient safety outcomes?

Significance of the Study

The following are some of the significant benefits of this research in various areas of nursing:

Nursing Education. This research highlights the vital role that nurses play in managing catheter-related bloodstream infections (CRBSIs), providing evidence-based nurse-led protocols to enhance the nursing curriculum, instructing nursing educators on effective infection prevention strategies, equipping aspiring nurses with practical knowledge and skills, and helping nursing students appreciate research-driven practices and the significance of systematic reviews in clinical decision-making.

Nursing Practice. This research demonstrates the effectiveness of nurse-led interventions, encouraging a sense of ownership and accountability in clinical practices, encouraging the adoption of standardized infection prevention protocols across healthcare settings, and giving nurses practical protocols to improve CRBSI management and hemodialysis patient safety.

Nursing Research. This research contributes to expanding the literature on infection prevention in hemodialysis by recognizing gaps in existing studies, establishing a foundation for future inquiries, motivating further studies to improve nurse-led interventions, and promoting collaboration between nursing and other medical disciplines.

Nursing Administration. This research shows the potential cost savings from reducing CRBSIs, supports the adoption of standardized nurse-led protocols, influences hospital policies, helps with resource allocation and budget management, and emphasizes the significance of giving nursing leaders the authority to champion infection prevention programs and organizational change.

Method

Research Design

This systematic review employed a rigorous and structured methodology to evaluate the effectiveness of nurse-led infection prevention protocols in reducing catheter-related bloodstream infections (CRBSIs) among hemodialysis patients using central venous catheters (CVCs). The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency, consistency, and reliability. In synthesizing evidence from existing peer-reviewed literature, the review aimed to identify effective nurse-led strategies, highlight current knowledge gaps in infection prevention practices, and propose informed recommendations for clinical practice and future research. The review was registered with PROSPERO (CRD420250651574) to ensure transparency and methodological integrity throughout the research process.

Data Sources

A comprehensive literature search was conducted across four major electronic databases: ScienceDirect, Google Scholar, ProQuest, and EBSCO. The search strategy was developed using the PICOS framework. It included a combination of controlled vocabulary and free-text keywords such as "nurse-led protocols," "infection prevention," "catheter-related bloodstream infections," "hemodialysis," and "central venous catheters." Boolean operators (AND, OR) and truncation symbols were used to refine the search and ensure inclusivity of relevant studies. The search was limited to studies published between January 2013 and December 2024 in English or with available English translations.

To enhance comprehensiveness, the reference lists of selected full-text articles were manually examined for additional eligible studies. The inclusion criteria prioritized peer-reviewed original research articles—specifically randomized controlled trials, cohort studies, quality improvement projects, and systematic reviews—that evaluated nurse-led interventions aimed at reducing CRBSIs in hemodialysis settings. Studies that did not involve nurse-led interventions or focused on populations not receiving hemodialysis through CVCs were excluded. This structured and transparent approach to data sourcing ensured that only high-quality and relevant evidence was included for synthesis.

Data Collection Procedure

Pre-Data Collection

Prior to the identification and selection of studies, approval was secured from the Dean of the Graduate School and the institutional ethics review board. This step ensured that the systematic review adhered to established ethical standards, particularly given the inclusion of primary studies involving human participants. Ethical clearance confirmed that the review complied with research governance guidelines and that all secondary data were managed with confidentiality and integrity. Furthermore, the systematic review was registered with PROSPERO under CRD420250651574, promoting transparency and methodological accountability.

During Data Collection

The data collection process involved a comprehensive and structured literature search across four electronic databases: Science Direct, Google Scholar, ProQuest, and EBSCO. Search terms and Boolean strings were developed based on the study's PICOS framework, incorporating combinations of keywords

such as "nurse-led protocols," "catheter-related bloodstream infections," "hemodialysis," "central venous catheters," and "infection prevention."

The search was restricted to peer-reviewed studies published between January 2013 and December 2024, and only studies available in English or with English translations were considered.

Identified studies were imported into a reference management system, where duplicate records were removed prior to screening. A two-stage screening process was employed: first, titles and abstracts were reviewed to eliminate studies that did not meet the inclusion criteria; second, full-text assessments were conducted to determine final eligibility based on criteria such as study design, population focus (patients on hemodialysis using CVCs), and the presence of nurse-led interventions targeting infection prevention. Two reviewers conducted data extraction independently, capturing key study characteristics, interventions, comparators, outcomes, and limitations. Any disagreements during extraction or screening were resolved through consensus or consulting a third reviewer.

Post-Data Collection

Following data extraction, the systematic review findings were synthesized narratively, employing thematic analysis to identify common patterns across interventions. Special attention was given to ensure that the included studies specifically addressed catheter-related bloodstream infections and reported measurable outcomes relevant to the study objectives.

The results are intended to be disseminated through submission to peer-reviewed journals in nursing or healthcare and may also be presented at academic conferences. Throughout the review process, ethical and academic standards were consistently upheld to ensure rigor, accuracy, and transparency.

Identification of the Studies

The identification of studies followed a systematic and structured approach to ensure comprehensive coverage of relevant literature. The search used pre-defined keywords and Boolean search strings based on the study's PICO (Population, Intervention, Comparison, Outcome) framework. This framework helped ensure that the search strategy remained focused on identifying studies relevant to nurse-led infection prevention protocols for catheter-related bloodstream infections (CRBSIs) in hemodialysis settings.

Electronic searches were performed across four databases: ScienceDirect, Google Scholar, ProQuest, and EBSCO. Keywords included terms such as "nurse-led protocols," "infection prevention," "catheter-related bloodstream infections," "hemodialysis," and "central venous catheters." Boolean operators (AND, OR) and truncation symbols were applied to refine search results and capture variations in terminology.

The study selection process consisted of two stages. First, duplicate records were identified and removed using reference management software. Then, a two-step screening process was implemented: an initial screening of titles and abstracts to exclude irrelevant studies, followed by a full-text review to assess eligibility based on the pre-established inclusion and exclusion criteria. Only studies that met the criteria regarding population, intervention, and outcome measures were included in the final synthesis.

PICO Element

Criteria	Determinants
Population	Patients undergoing hemodialysis who utilize central venous catheters (CVCs) as their primary vascular access.

Intervention	Nurse-led infection prevention protocols, such as hygiene training, use of antiseptic dressings, and implementation of catheter care bundles.
Comparison	Standard care practices or alternate infection prevention methods.
Outcome	- Reduction in CRBSI incidence (e.g., CRBSI episodes per 1,000 catheter days). - Improvement in nursing practice adherence rates. - Patient safety metrics such as adverse event rates and length of hospital stay. - Percentage of patients achieving infection-free outcomes post-intervention.
Study Design	Randomized controlled trials

Search strings and databases

Database	Search string
Science Direct	("nurse-led protocols" OR "nurse-led intervention" OR "interventions") AND ("infection prevention" OR "catheter-related bloodstream infection" OR "CRBSI") AND ("hemodialysis" OR "central venous catheter" OR "vascular access")
Google Scholar	("nurse-led protocols" AND "infection prevention" AND "CRBSI" AND "hemodialysis")
Proquest	("infection prevention" OR "nurse-led care") AND ("catheter-related bloodstream infection" OR "CRBSI") AND ("hemodialysis" OR "dialysis")
EBSCO	("infection prevention" OR 'nurse-led care") AND ("catheter-related bloodstream infection" OR "CBRSI') AND ("hemodialysis" OR "dialysis')

Minimizing Bias in Study Identification and Selection

To minimize bias in the identification and selection of studies, a comprehensive and structured search strategy was implemented. Multiple databases—ScienceDirect, Google Scholar, ProQuest, and EBSCO—were systematically searched, and reference lists of included full-text articles were manually reviewed to identify additional relevant studies. This strategy ensured a wide and inclusive coverage of the literature and helped reduce the risk of omitting pertinent evidence.

To maintain objectivity and rigor in the selection process, two independent reviewers screened all retrieved titles, abstracts, and full-text articles against the predefined inclusion and exclusion criteria. Disagreements at any stage were resolved through discussion and, if necessary, arbitration by a third reviewer. This process helped ensure consistent application of criteria and reduced the potential for selection bias.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for this systematic review were established to ensure that the selection of studies closely aligned with the objective of evaluating the effectiveness of nurse-led infection prevention protocols in reducing catheter-related bloodstream infections (CRBSIs) in hemodialysis settings. These criteria were designed to assess the relevance, focus, and methodological quality of each study included in the review.

As part of the study selection process, the PROSPERO international database of registered systematic reviews was consulted to verify the originality of the topic and to ensure that none of the included studies had already been synthesized in existing reviews. This review was also formally registered under the

PROSPERO registration number CRD420250651574. All identified records were screened for eligibility based on predefined inclusion and exclusion criteria. Duplicate entries were removed using reference management software prior to the screening process.

Studies were included if they met the following key criteria: (1) the population comprised patients undergoing hemodialysis using central venous catheters (CVCs) as their primary vascular access; (2) the intervention involved nurse-led protocols or interventions—such as structured infection prevention bundles, hygiene training, or educational programs—demonstrating direct involvement of nursing professionals; and (3) the study reported measurable outcomes such as CRBSI incidence, improvements in nursing practice, or relevant patient safety indicators. Only peer-reviewed studies were considered, including randomized controlled trials, cohort studies, pre- and post-intervention studies, and systematic reviews. To maintain the relevance and accessibility of findings, only studies published in English or with available English translations were included and within January 2013 to December 2024.

Conversely, studies were excluded if they did not focus on nurse-led protocols or interventions, if the target population was unrelated to hemodialysis or CRBSIs, or if nurses were not the primary implementers of the interventions. Studies that did not report relevant outcome measures, such as infection rates or nursing practice changes, were also excluded. Editorials, letters to the editor, opinion pieces, case reports, and non-peer-reviewed publications were not eligible. Additionally, studies published in languages other than English without an accessible translation were excluded.

The inclusion criteria distinguished between nurse-led protocols which refer to structured, evidence-based clinical practices led by nurses and nurse-led interventions, which include broader education-based or practice-enhancement strategies. This distinction helped ensure that all included studies fell within the scope of nursing practice and contributed meaningfully to the evaluation of infection prevention efforts in hemodialysis care.

Inclusion and exclusion criteria for the systematic review.

Criteria	Inclusion	Exclusion
Research Design	Peer-reviewed studies evaluating nurse-led protocols or interventions for CRBSI prevention.	Studies not focused on nurse-led protocols, interventions, or CRBSI prevention.
Population	Patients undergoing hemodialysis and managed with central venous catheters.	Studies focusing on non-hemodialysis populations or non-catheter-related infections.
Intervention	Nurse-led protocols (e.g., infection control bundles, hygiene training) and interventions (e.g., education).	Interventions not led by nurses or unrelated to infection prevention.
Publication Type	Original research, randomized control trials	Editorials, letters, opinions, and case reports.
Publication Language	English-language studies (or with available English translations).	Studies in languages other than English without translations.
Publication Date	Studies published from January 2013 to December 2024.	Studies published before 2013.
Discipline	Nursing	Non-nursing studies

Data Synthesis and Analysis

This systematic review employed a thematic analysis approach to synthesize findings from the included studies on nurse-led infection prevention protocols for reducing catheter-related bloodstream infections (CRBSIs) in hemodialysis settings. Given the methodological diversity of the included studies which ranged from randomized controlled trials to quality improvement projects, a narrative and qualitative synthesis was deemed the most appropriate method to explore recurring patterns and themes across varied clinical contexts.

The data analysis focused on extracting key elements related to the interventions, their implementation, and reported outcomes. Using a structured data extraction form, relevant information such as study characteristics, population, type of nurse-led intervention, and infection-related outcomes was organized for comparison. Through inductive coding, themes were identified by grouping studies with similar intervention approaches and outcome narratives.

Thematic analysis allowed the review to uncover what interventions were used but also how they were implemented, how nurses influenced patient safety practices, and under what conditions those interventions were most effective. This method also facilitated the exploration of context-specific factors such as institutional support, staff engagement, patient compliance, and behavioral change—elements critical to understanding the success or limitations of nurse-led CRBSI prevention strategies.

Ultimately, this approach provided a comprehensive and in-depth understanding of the mechanisms by which nurse-led protocols contribute to infection prevention in hemodialysis care. By identifying themes that cut across diverse study settings, the review highlights best practices and gaps in the literature, offering insights into effective nursing strategies that promote patient safety and quality care.

Quality Assessment

All studies included in this systematic review underwent a rigorous quality assessment to ensure the reliability and validity of their findings. Given the nature of the included studies, which were primarily randomized controlled trials, pilot trials, cohort studies, and quality improvement projects, the CONSORT (Consolidated Standards of Reporting Trials) checklist was used as the primary appraisal tool. This instrument was selected for its established credibility in evaluating methodological transparency and reporting quality of intervention-based research.

Each study was assessed across core CONSORT domains, including the clarity of study objectives, description of the intervention, methods of randomization or group assignment, outcome measurement, reporting of results, and handling of potential bias. Scores were assigned to each study based on a 26-point scale adapted from the CONSORT criteria, with higher scores reflecting greater methodological rigor.

The assessment revealed that all eight included studies met acceptable quality thresholds, with scores ranging from 22/26 to 25/26, indicating moderate to high quality. While most studies demonstrated strong adherence to standardized reporting practices, common limitations included incomplete reporting of allocation concealment, limited blinding of participants or assessors, and variation in follow-up duration. These limitations were noted but did not warrant exclusion, as the overall methodological quality of the studies remained sufficient to support their inclusion in the synthesis.

Using a standardized quality assessment process helped ensure that only studies with robust and transparent methodologies were included, enhancing the credibility and dependability of the systematic review's findings.

Ethical Considerations

Ethical considerations were central to the conduct of this systematic review, particularly due to the clinical nature of the included studies and the vulnerable patient populations they involved. Although the review did not involve direct interaction with human participants or primary data collection, strict adherence to ethical principles was maintained throughout the research process. Only aggregated data from published, peer-reviewed studies were used, and all included studies anonymized individual patient information to ensure privacy and confidentiality.

Eligibility criteria for inclusion in this review required that each selected study demonstrate clear adherence to ethical standards, including approval from an institutional review board or ethics committee and documented informed consent from participants where applicable. Studies lacking such documentation were excluded to uphold ethical integrity and ensure that the synthesis was based on ethically sound research.

The review process was conducted with a commitment to transparency, honesty, and academic rigor. All findings were reported accurately, and potential biases and limitations were explicitly acknowledged. Proper citation and attribution were applied consistently to respect intellectual property rights and support academic integrity. Attention was also given to the diversity of patient populations represented in the included studies, with consideration for variations in age, gender, ethnicity, and comorbid conditions. This approach ensured that the review's findings were both inclusive and broadly applicable to different healthcare settings.

Data used in the review was securely stored in a password-protected database, with backup copies maintained on an encrypted drive. Only aggregated and anonymized information was retained. In accordance with ethical research practices, these data will be kept for five years, after which electronic files will be permanently deleted and any physical records will be securely shredded.

The study was conducted under the supervision and oversight of the San Pedro College Research Ethics Committee (SPC-REC), which approved the review protocol and may conduct periodic monitoring to ensure continued compliance with ethical standards. The principal investigator, a licensed nurse with nearly two decades of experience in infection control and healthcare management, was guided by an experienced adviser and research panel throughout the project. Institutional support from San Pedro College, including access to academic databases and research tools, provided the necessary infrastructure for the ethical and methodologically sound completion of this systematic review.

These measures collectively ensured that the review was conducted in accordance with the highest ethical standards, contributing meaningfully to the body of knowledge on nurse-led infection prevention protocols in hemodialysis settings.

Results

This section presents the findings derived from the collected data based on the study's established review question, which aimed to evaluate the effectiveness of nurse-led infection prevention protocols in reducing catheter-related bloodstream infections (CRBSIs) among hemodialysis patients using central venous catheters. The systematic review followed a rigorous selection process to ensure that only studies aligned with the defined PICOS criteria were included.

A comprehensive literature search was conducted across major electronic databases and citation tracking platforms, resulting in a total of 572 records retrieved from ScienceDirect (363), Google Scholar (82), ProQuest (122), and EBSCO (5). After removing 14 duplicates, 549 studies were excluded during the

initial screening phase based on title, abstract, and methodological design. A full-text review was then conducted on the remaining studies, including eight (8) eligible studies that met all criteria for relevance, quality, and population focus. Figure 1 summarizes the methodology used to select the studies included in this review.
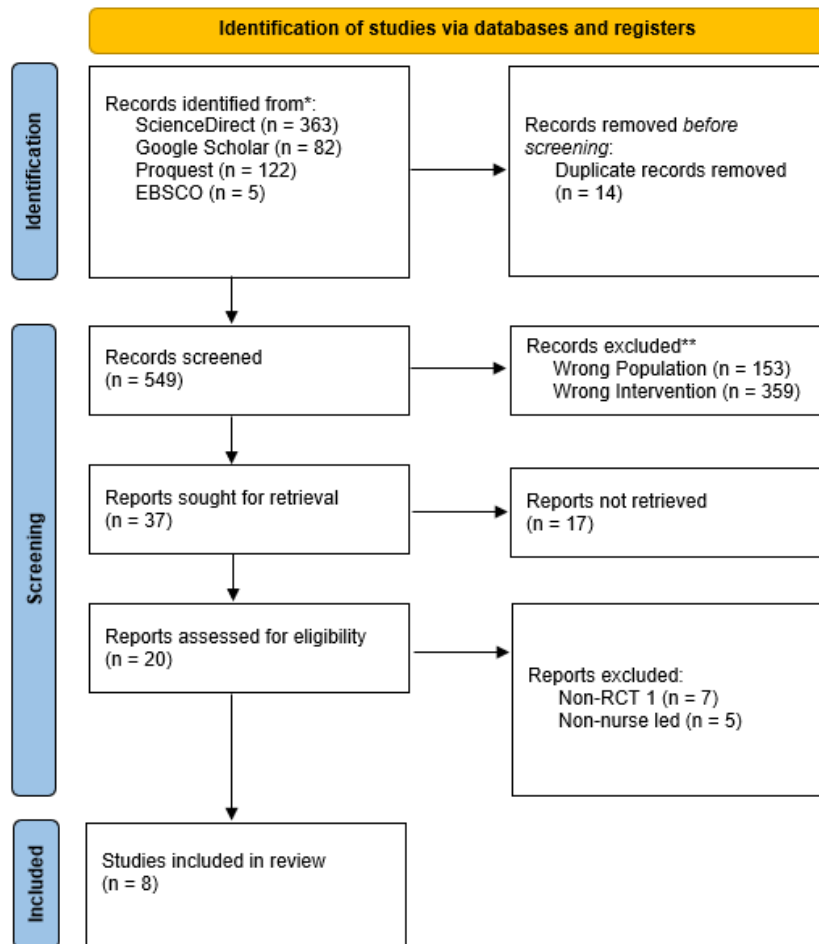

Figure 1. PRISMA Diagram

Characteristics of the Included Studies

Study Design

This systematic review includes eight studies employing a variety of research designs to evaluate the effectiveness of nurse-led infection prevention protocols in reducing catheter-related bloodstream infections (CRBSIs) among hemodialysis patients using central venous catheters (CVCs). The selected studies include randomized controlled trials (RCTs), pilot RCTs, retrospective and prospective cohort studies, stepped wedge cluster-randomized trials, and quality improvement initiatives. These diverse methodologies reflect the multifaceted nature of infection control practices in clinical settings and provide both experimental and real-world evidence on the role of nurses in CRBSI prevention.

Study Period

The studies were conducted between 2013 and 2024, encompassing over a decade of evolving clinical practices and infection control strategies in hemodialysis care. This timeframe captures both foundational

interventions and more recent, evidence-based nurse-led approaches, offering insight into how nursing practice has adapted to address the persistent challenge of CRBSIs in various hemodialysis environments.

Study Location

The included studies were conducted across eight countries, representing a broad international scope. These countries include China, Saudi Arabia, Germany, Canada, the United States, Australia, Egypt, and Qatar, covering diverse healthcare systems and dialysis infrastructures. This geographical distribution enhances the generalizability of the findings and reflects the global relevance of nurse-led infection prevention strategies. Differences in healthcare policy, nurse training, and resource availability across these settings provide valuable comparative insights into the effectiveness and adaptability of such interventions.

Methodological Quality or Risk of Bias of Included Studies

The methodological quality of the included studies was assessed using the CONSORT (Consolidated Standards of Reporting Trials) checklist, a widely accepted tool for evaluating the rigor and transparency of randomized trials and intervention studies. This appraisal process ensured that the selected studies adhered to core standards of research design, reporting, and analysis relevant to clinical interventions in infection control. The CONSORT criteria assessed elements such as randomization methods, intervention clarity, outcome reporting, participant flow, and risk of bias.

Across the eight included studies, appraisal scores ranged from 22/26 to 25/26, indicating moderate to high methodological quality. The randomized controlled trials and pilot RCTs demonstrated strong adherence to CONSORT reporting standards, particularly in clearly defining their objectives, interventions, and outcome measures related to catheter-related bloodstream infections (CRBSIs). Cohort studies and quality improvement projects also exhibited robust methodological features, such as structured implementation of nurse-led protocols and consistent monitoring of CRBSI outcomes.

While most studies effectively minimized the risk of bias, common limitations included incomplete reporting of allocation concealment, lack of blinding, and variation in follow-up procedures. Despite these limitations, the overall quality of evidence supports the validity of the synthesized findings. The strong methodological foundation of these studies contributes to a reliable evaluation of the impact of nurse-led protocols on CRBSI reduction in hemodialysis settings.

PICO Components of the Included Studies
Population

All eight studies included in this systematic review involved adult patients undergoing hemodialysis using central venous catheters (CVCs) as their primary vascular access. These studies were conducted across diverse clinical settings, ranging from outpatient dialysis centers to inpatient hospital units, offering a comprehensive view of nurse-led infection prevention strategies in different healthcare environments. The sample sizes varied significantly, enhancing the breadth of the findings. He et al. involved 70 patients in a hospital setting in China, while Yang et al. recruited 244 patients, equally divided into two groups, at Ruijin Hospital, also in China. Hamid et al. conducted their study on ambulatory hemodialysis patients in Qatar, focusing on a smaller cohort. Kosa et al. included 68 patients from 11 hemodialysis units across Ontario, Canada. AlHulays et al. studied 111 patients from Saudi Arabia, while Roderman et al. evaluated patients across nine hospitals spanning three U.S. states. Weikert et al. provided the largest sample,

analyzing data from 11,251 hemodialysis patients across 43 outpatient facilities in Germany, and Kotwal et al. monitored 6,364 patients across 37 renal services in Australia. This broad range of geographical locations and settings strengthens the applicability and relevance of the results to a global healthcare audience. These selected studies form the basis for the synthesis and analysis presented in the succeeding sections as depicted in Table 1.

Intervention

In terms of interventions, each study applied nurse-led strategies specifically designed to reduce catheter-related bloodstream infections (CRBSIs). He et al. implemented targeted nursing interventions focusing on professional training related to aseptic techniques and catheter care. Yang et al. adopted the Plan-Do-Check-Act (PDCA) quality improvement model to systematically enhance nursing practices. Hamid et al. introduced a bundled intervention emphasizing nurse education, catheter site surveillance, and rigorous adherence to hand hygiene protocols. Meanwhile, Kosa et al. piloted the Hemodialysis Infection Prevention Protocol Ontario—Shower Technique (HIPPO-ST), a novel approach allowing patients to maintain hygiene without compromising catheter sterility. AlHulays et al. developed and implemented a Dialysis Event Prevention Bundle comprising six evidence-based nursing practices. Roderman et al. led a multidisciplinary but nurse-driven standardization of dialysis catheter care protocols across multiple hospitals. Weikert et al. designed a multimodal prevention strategy centered on nurse-led initiatives such as hand hygiene training, infection surveillance, and real-time feedback. Finally, Kotwal et al. organized a multifaceted intervention bundle addressing catheter insertion, maintenance, and removal processes within a large-scale clinical network. These interventions reinforced the pivotal role of nurses as frontline agents of infection prevention.

Across all studies, nurse-led interventions were compared against standard or routine care practices. In the studies by He et al., Yang et al., and Hamid et al., nurse-led interventions were measured against conventional nursing practices. Kosa et al. compared the effectiveness of HIPPO-ST users with those receiving standard catheter care. AlHulays et al. and Roderman et al. employed before-and-after comparisons to assess infection rates pre- and post-implementation of bundled interventions. Weikert et al. and Kotwal et al. utilized stepped wedge cluster randomized designs, allowing for a phased and controlled transition from standard care to nurse-led interventions across different facilities. This comparative approach across all studies ensured that the impact of nurse-led interventions was rigorously evaluated against existing practices.

Comparison

Across all studies, nurse-led interventions were compared against standard or routine care practices. In the studies by He et al., Yang et al., and Hamid et al., nurse-led interventions were measured against conventional nursing practices. Kosa et al. compared the effectiveness of HIPPO-ST users with those receiving standard catheter care. AlHulays et al. and Roderman et al. employed before-and-after comparisons to assess infection rates pre- and post-implementation of bundled interventions. Weikert et al. and Kotwal et al. utilized stepped wedge cluster randomized designs, allowing for a phased and controlled transition from standard care to nurse-led interventions across different facilities. This comparative approach across all studies ensured that the impact of nurse-led interventions was rigorously evaluated against existing practices.

Outcomes

The primary outcome measure for all studies was the incidence of catheter-related bloodstream infections, typically reported in infections per 1,000 catheter days. Results varied across studies but generally favored the nurse-led interventions. He et al. reported a significant reduction in CRBSI rates after implementing targeted interventions. Yang et al. demonstrated a striking decrease from 8.8 to 0.8 infections per 1,000 catheter days using the PDCA model. Hamid et al. reported a 99% reduction in CRBSI incidence through a bundled preventive approach. Although Kosa et al. did not find a significant reduction in CRBSI rates following HIPPO-ST implementation, they observed a notable improvement in patient compliance with hygiene practices. AlHulays et al. found a statistically significant decrease in infection rates after introducing the Dialysis Event Prevention Bundle. Roderman et al. recorded an impressive 88% reduction in central line-associated bloodstream infection (CLABSI) rates. Weikert et al. documented a 56% reduction in dialysis-associated infections after applying a multimodal, nurse-driven prevention strategy. On the other hand, Kotwal et al., despite implementing a large-scale multifaceted intervention, did not observe a significant change in CRBSI rates, a result likely influenced by the already low baseline infection rates in their study population.

Synthesis from the Included Studies

Synthesizing findings across the eight studies reveals a strong and consistent pattern favoring the effectiveness of nurse-led infection prevention protocols in reducing CRBSIs among hemodialysis patients. Several common elements contributed to the success of these interventions, including structured and continuous nurse education on aseptic techniques, emphasis on strict hand hygiene practices, standardized catheter care bundles often integrating chlorhexidine-based products, and the use of continuous monitoring and feedback mechanisms to sustain improvements. These similarities highlight the essential role of evidence-based, nurse-led practices in infection prevention efforts.

However, differences also emerged across the studies. While most studies demonstrated significant reductions in infection rates, the extensive randomized studies by Kotwal et al. and Kosa et al. did not find statistically significant effects. In Kotwal et al., the low baseline CRBSI rates might have made further reductions difficult to achieve, while in Kosa et al., the HIPPO-ST intervention, focused more on patient hygiene behavior than direct catheter management, did not result in notable infection control improvements. Furthermore, multicenter interventions such as those led by Roderman et al. and Weikert et al. were notably successful but required substantial institutional support, leadership engagement, and interdisciplinary collaboration to achieve positive outcomes. These findings suggest that while nurse-led interventions are generally effective, their success depends heavily on contextual factors such as organizational backing, adherence to standardized protocols, and the nature of the interventions.

In conclusion, the evidence gathered from these eight studies clearly supports the effectiveness of nurse-led strategies for the prevention of catheter-related bloodstream infections in hemodialysis patients. The interventions were most successful when they were comprehensive, systematically implemented, and reinforced by organizational leadership and multidisciplinary collaboration. While variations in success were observed, particularly in large multisite trials or interventions primarily centered on patient behavior, the overall trend highlights that empowering nurses with the tools, training, and institutional support necessary for infection prevention can significantly enhance patient safety and clinical outcomes in dialysis settings.

Table 1
Synthesis of the Included Studies

Study No.	First Author	Title of the Study	Study Design	Study Period	Country	Appraisal Score	Population	Intervention	Comparison	Outcome	Nurse-Led Infection Prevention Interventions	Findings on Effectiveness
1	Yang	Effects of a Quality Improvement Program to Reduce Central Venous Catheter-Related Infections in Hemodialysis Patients	Randomized Controlled Pilot Study	November 2017 – November 2018	China	22/26	Hemodialysis patients using central venous catheters (CVCs)	PDCA (Plan-Do-Check-Act) method for CVC management	Routine care vs PDCA group	Primary: Incidence of CRBSI (0.8 vs 8.8 per 1,000 catheter days), Secondary: Nursing satisfaction, Quality of life	Nurse-led management (adequate nursing practices critical for infection prevention, part of PDCA cycle implementation)	The PDCA method significantly reduced CRBSI incidence from 8.8 to 0.8 per 1,000 catheter days. Additionally, patient satisfaction and quality of life were improved in

													the PDCA group compared to routine care.
2	He	Prevention of Catheter-Associated Bloodstream Infections in Hemodialysis Patients	Randomized Controlled Trial	January 2020 – January 2023	China	23/26	70 hemodialysis patients with central venous catheters	Targeted preventive nursing vs conventional nursing	Conventional care	Primary: Incidence of CRBSIs, secondary: Quality of nursing, stress level, and quality of life	Nurse-led targeted preventive nursing, including training on catheter care, aseptic techniques, and psychological support	Targeted preventive nursing significantly reduced CRBSI incidence from 14.29% to 2.86%, shortened catheter retention time, improved

Cont… Study No.	First Author	Title of the Study	Study Design	Study Period	Country	Appraisal Score	Population	Intervention	Comparison	Outcome	Nurse-Led Infection Prevention Interventions	Findings on Effectiveness
												quality of nursing care, and enhanced patient quality of life and reduced stress levels compared to conventional care.
3	AlHulays	The Impact of the Dialysis Event Prevention Bund	Retrospective and Prospective Cohort Study	Nov 2023 – Jun 2024	Saudi Arabia	22/26	111 hemodialysis patients with permanent catheters	Dialysis event prevention bundle consisting of 6 components: catheter connection,	Pre-implementation vs post-implementation dialysis event rates	Primary: Reduction in dialysis event rate, Secondary: Positive	Nurse-led aspects in catheter care, aseptic techniques, hand	The intervention led to a 51% reduction in dialysis events, with signifi

		le on the Reduction in Dialysis Event Rate in Patients with Catheter						disconnection, catheter exit site care, dialysis station disinfection, medication preparation, medication administration		blood culture, IV antimicrobial start, infection at vascular access site	hygiene, and infection control compliance	cant decreases in IV antimicrobial starts (45.5%), positive blood culture (55%), and vascular access site infection (100% reduction). Nurses played a key role in implementing infection control

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Study No.	First Author	Title of the Study	Study Design	Study Period	Country	Appraisal Score	Population	Intervention	Comparison	Outcome	Nurse-Led Infection Prevention Interventions	Findings on Effectiveness
												measures.
4	Weikert	Effect of a Multimodal Prevention Strategy on Dialysis-Associated Infection Events in Outpatients Receiving Haemodialysis	Stepped Wedge, Cluster-Randomized Trial	October 2019 – September 2021	Germany	24/26	11,251 haemodialysis patients	Multimodal prevention strategy including surveillance, hand hygiene (HH) compliance, feedback, intensified training in aseptic procedures, and patient flyer	Pre-implementation vs post-implementation dialysis event rates	Primary: Incidence of dialysis-associated infections (DAIE), Secondary: HH compliance	Nurse-led involvement in HH compliance, feedback on infection data, and teaching aseptic techniques	The intervention significantly reduced DAIE incidence by 56%, particularly in patients with central venous catheters (CVCs). HH compliance increased from

												58% to 65%. The strategy effectively reduced bloodstream infections, antimicrobial starts, and local access-site infections.
5	Kosa	Hemodialysis Infection Prevention Protocols Ontario—Shower Technique (HIPPO-ST):	Pilot Randomized Controlled Trial	Nov 2012 – Dec 2014	Canada	23/26	68 hemodialysis patients with healed catheter entry sites	HIPPO-ST (Shower Technique) training + standard catheter care vs. standard	Primary: CRB rate, Secondary: Entry site infections, satisfaction	No significant reduction in CRB Rate; improved patient compliance with the	Nurse-led care for catheter entry site, dressing changes, hygiene practices, and	No significant difference in CRB rates between the groups. However, HIPPO-ST showed high

											patient	

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Study No.	First Author	Title of the Study	Study Design	Study Period	Country	Appraisal Score	Population	Intervention	Comparison	Outcome	Nurse-Led Infection Prevention Interventions	Findings on Effectiveness
		A Pilot Randomized Trial						catheter care alone		showering technique (88.4%) and increased patient satisfaction	education on the HIPPO-ST technique	patient compliance (88.4%) and satisfaction with catheter care. No unexpected harms were observed.
6	Roderman	Central Line-Associated Bloodstream Infection Reduction in Hemodialysis Patient	Quality Improvement Project	2020-2023	USA	25/26	4112 hemodialysis patients	Standardized interventions for infection prevention, including chlorhexidine	Pre- and post-intervention CLABSI rates	Primary: Reduction in CLABSI rates, Secondary: Improved patie	Nurse-led involvement in monitoring line access, CHG pad use, and daily	An 88% reduction in CLABSI rates was achieved after the intervention,

s Across 9 Hospitals and 3 States	gluconate (CHG) impregnated caps, daily line surveillance, and staff education	nt safety, infection prevention compliance	surveillance, along with training and audits	with improved compliance to infection control practices and significant reduction in infections related to hemodialysis lines. The intervention showed a 71% overall reduction in CLABSI occurrences originating from HD lines.

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Study No.	First Author	Title of the Study	Study Design	Study Period	Country	Appraisal Score	Population	Intervention	Comparison	Outcome	Nurse-Led Infection Prevention Interventions	Findings on Effectiveness
7	Kotwal	Multifaceted Intervention to Reduce Haemodialysis Catheter-Related Bloodstream Infections	Stepped wedge, cluster-randomized trial	December 2016 – March 2020	Australia	24/26	6364 patients across 37 renal services	A multifaceted bundle of care that included catheter insertion, maintenance, and removal procedures	Baseline phase vs intervention phase	Primary: Rate of CRBSIs, Secondary: Other infection-related outcomes	Nurse-led components included staff education on catheter care, adherence to antiseptic techniques, and infection control measures	No significant reduction in CRBSI rates. The rate of infections was slightly higher in the intervention phase, suggesting that the multifaceted care bundle did not significantly impact

| 8 | Hamid | Effective Prevention Bundle to Eliminate Catheter-Related Bloodstream Infections in Ambulatory Hemodialysis Patients | Multidisciplinary quality improvement project | 2011-2017 | Qatar | 25/26 | 99 hemodialysis patients | Infection prevention bundle (including education, improved catheter care, and surveillance) | Pre-implementation vs post-implementation CRBSI rates | Primary: Reduction in CRBSI rates, Secondary: Adherence to infection control practices | Nurse-led education on catheter care, hygiene practices, surveillance, and patient/family education | The intervention resulted in a 99% reduction in CRBSI rates (from 1.4/1,000 CVC days to 0.014/1,000 CVC days), demonstrating the effectiveness |

(top of column, continued text:) infection rates despite the intervention's widespread use.

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Study No.	First Author	Title of the	Study Design	Study Period	Country	Appraisal Score	Population	Intervention	Comparison	Outcome	Nurse-Led Infection	Findings on Effectiveness

Study	Prevention Interventions
	of the prevention bundle. The success was attributed to the multidisciplinary team approach, with nurses playing a central role in education, surveillance, and protocol adherence.

Discussion

This systematic review examined the effectiveness of nurse-led infection prevention protocols in reducing catheter-related bloodstream infections (CRBSIs) among hemodialysis patients using central venous catheters (CVCs). Two theoretical frameworks provided the lens for interpreting the findings: Nola Pender's Health Promotion Model (HPM) and the Donabedian Model of Quality of Care. The Health Promotion Model emphasizes individual empowerment and behavior change, while the Donabedian Model highlights how structure and process improvements in healthcare delivery contribute to better outcomes. Together, these frameworks enabled a comprehensive understanding of the pathways through which nurse-led interventions achieved impact.

Three thematic patterns emerged across the eight included studies. The first theme focused on structured protocols and care bundles. Standardization of catheter care practices, such as predefined dressing protocols, antiseptic techniques, and bundle interventions, consistently demonstrates substantial improvements in infection prevention. For example, Roderman et al. achieved an 88% reduction in CRBSIs across multiple hospitals by implementing a standardized, nurse-led bundle, while Hamid et al. documented a 99% decrease through a multidisciplinary protocol emphasizing nursing education and patient monitoring. AlHulays et al. also reported significant reductions in dialysis-associated infections

through targeted, nurse-led protocols. Although Kotwal et al. did not find statistically significant changes, they underscored the challenges of sustaining protocol fidelity across multiple diverse settings—a cautionary note that complex interventions require consistent support to succeed. These findings affirm Donabedian's assertion that structural reforms and consistent processes are critical to achieving high-quality care outcomes.

The second major theme centered on quality improvement and cyclical strategies. Studies within this theme applied systematic, feedback-driven models to promote continual advancement in infection prevention. Yang et al. demonstrated that using the Plan-Do-Check-Act (PDCA) cycle led to substantial CRBSI reductions by enabling iterative refinement of clinical practices. Similarly, Weikert et al. utilized a multimodal, nurse-led strategy incorporating real-time surveillance and hand hygiene audits, achieving a 56% reduction in dialysis-associated infections. These findings illustrate that embedding continuous quality improvement methodologies into daily nursing practice can strengthen infection control outcomes. They align with both Donabedian's process component and the HPM's focus on reinforcing behaviors that promote health and safety.

The third thematic pattern involved behavior-focused interventions. These studies emphasized education, engagement, and empowerment of nursing staff and patients. He et al. demonstrated that targeted training in hygiene and infection control, along with psychological support for patients, resulted in improved quality of life and infection outcomes. Kosa et al., through the HIPPO-ST intervention, found improved patient compliance and satisfaction, even though statistically significant CRBSI reductions were not observed. These studies directly align with the Health Promotion Model's concepts of self-efficacy, perceived benefits, and the role of supportive environments in encouraging health behavior change. They reinforce the notion that empowering both providers and patients is essential to sustainable infection prevention.

The applicability of these findings to the Philippine hemodialysis context—and more broadly to other low- and middle-income countries (LMICs)—is both clear and urgent. In the Philippines, hemodialysis facilities often operate under resource-constrained conditions, with variability in staffing ratios, access to antiseptic supplies, and standardization of infection control protocols. Many dialysis centers continue to face challenges with the consistent implementation of evidence-based catheter care practices, partly due to limitations in continuous nurse training, turnover of personnel, and resource availability.

Similarly, in other LMICs, the realities of constrained healthcare infrastructure mirror these challenges. The results of this review suggest that even in resource-limited settings, nurse-led initiatives focused on structured protocols, standardized bundles, and education-driven behavior change can significantly improve outcomes. Contextual adaptations, such as using locally available antiseptic solutions, training programs adapted to cultural practices, and reinforcement through continuous quality improvement loops, can make these interventions feasible and effective even without high-cost technologies. Philippine hemodialysis centers could benefit from embedding nurse-led infection prevention bundles into their standard operating procedures, supported by regular training workshops and quality audits tailored to the local environment.

The findings of this systematic review also carry important implications for practice, policy, and future research. In terms of clinical practice, the integration of nurse-led, standardized infection prevention bundles should become a core component of dialysis care. Nurse managers and dialysis unit heads must prioritize continuous professional development focused on catheter care, hand hygiene, and infection surveillance. At the policy level, health authorities and dialysis accreditation bodies should mandate

minimum standards for catheter care bundles and require regular reporting on CRBSI rates as part of facility licensure and quality assurance programs. Institutional leadership must also support nurses through staffing models that allow for proper education, monitoring, and compliance audits.

Future research should focus on evaluating the long-term sustainability of nurse-led interventions, especially in resource-limited settings. More studies are needed to explore the cost-effectiveness of various intervention strategies, as well as to develop context-specific bundles that are adapted for LMIC conditions without compromising effectiveness. Additionally, exploring the role of patient education interventions co-led by nurses and patient advocates could yield new strategies for reinforcing self-management practices among dialysis patients.

The thematic synthesis of the included studies revealed that nurse-led infection prevention protocols are most effective when they are comprehensive, contextually adapted, and supported by leadership and multidisciplinary collaboration. The Health Promotion Model emphasizes the behavioral empowerment of nurses and patients, while the Donabedian Model underscores the importance of structured, standardized processes in healthcare delivery. Together, they highlight the dual pathway—through behavior and system change—by which infection prevention in hemodialysis settings can be successfully achieved. Moving forward, embedding structured care bundles, fostering continuous quality improvement, and investing in education-driven behavior change will be essential strategies for enhancing patient safety and reducing catheter-related bloodstream infections both in the Philippines and around the world.

Summary, Conclusion, and Recommendations

This systematic review synthesized evidence from eight peer-reviewed studies examining the effectiveness of nurse-led infection prevention protocols in reducing catheter-related bloodstream infections (CRBSIs) among patients undergoing hemodialysis with central venous catheters (CVCs). The studies, conducted across diverse global settings, utilized a range of research designs including randomized controlled trials, quality improvement projects, and cohort studies. Interventions were broadly categorized into structured care bundles, cyclical quality improvement strategies, and behavior-focused education programs targeting both nurses and patients.

The findings consistently indicated that nurse-led interventions contribute to a reduction in CRBSI rates when protocols are well-defined, systematically implemented, and supported by continuous monitoring and institutional backing. Standardized care bundles and quality improvement models proved effective in enhancing adherence to infection control practices. While not all interventions led to statistically significant reductions, many studies showed improvements in secondary outcomes such as nursing adherence, patient satisfaction, and hand hygiene compliance. The review's thematic analysis grouped the studies into three themes—structured protocol and care bundles, quality improvement and cyclical strategies, and behavior-focused educational interventions—each highlighting the multifaceted role of nursing leadership in infection prevention.

The application of Nola Pender's Health Promotion Model and the Donabedian Model of Quality of Care provided a comprehensive lens to evaluate these interventions. The HPM emphasized the empowerment of nurses and patients through knowledge and self-efficacy, while the Donabedian framework facilitated assessment of structural, process, and outcome-level elements of care delivery.

This review concludes that nurse-led infection prevention protocols are effective in reducing CRBSIs in hemodialysis settings, particularly when interventions are structured, evidence-based, and institutionally supported. The integration of behavioral education, consistent protocol implementation, and cyclical

quality improvement processes demonstrates the unique value nurses bring to infection control initiatives. Nurse-led models not only enhance compliance with evidence-based practices but also contribute to a culture of safety, patient empowerment, and continuous improvement.

The combined application of the Health Promotion Model and the Donabedian Model underscores that the success of these interventions depends on both individual behavior change and supportive organizational structures. Empowering nurses through education and leadership roles, while establishing reliable systems for protocol adherence and monitoring, leads to measurable improvements in patient safety and quality of care.

Based on the findings of this systematic review, the following recommendations are proposed to strengthen infection prevention efforts in hemodialysis settings:

First, nursing leadership in infection prevention should be formally strengthened. It is recommended that dedicated infection prevention nurse leaders be designated within dialysis units, tasked with overseeing the development, implementation, and monitoring of CRBSI prevention protocols. Empowering nursing leadership ensures ownership and accountability, which are critical for sustaining infection control measures.

Second, standardized catheter care bundles incorporating evidence-based practices should be adopted universally. These bundles must include the use of chlorhexidine-impregnated dressings, strict aseptic techniques during catheter connection and disconnection, and robust hand hygiene protocols. Compliance with these bundles should be regularly audited to ensure fidelity to best practices.

Third, continuous quality improvement (CQI) frameworks, such as the Plan-Do-Check-Act (PDCA) cycle or stepped-wedge implementation models, should be integrated into routine dialysis care. This will allow for ongoing evaluation of infection prevention measures and iterative improvements based on data-driven feedback.

Fourth, education initiatives should be enhanced for both nurses and patients. Nurse education programs should include structured training modules that comprehensively cover handling all types of central venous catheters—tunneled catheters, nontunneled catheters, and peripherally inserted central catheters (PICC lines). For patients, targeted education specifically on hygiene protocols must be developed and disseminated through information campaigns, including flyers or leaflets on catheter care, hand hygiene, and early infection signs to foster better self-care practices.

Fifth, multidisciplinary collaboration must be actively promoted. Nurses, nephrologists, infection control specialists, and administrative leaders should co-develop infection prevention strategies and align institutional goals to ensure sufficient resource allocation and sustainability.

Lastly, future research must explore the long-term impact of nurse-led infection prevention interventions, particularly in low-resource settings. Further studies should use robust designs and standardized outcome measures to assess clinical efficacy, cost-effectiveness, and patient-centered outcomes, supporting global efforts to reduce CRBSI rates even in the most resource-constrained environments.

In support of the recommendations presented herein, a structured Plan of Action has been created and is included in the appendices for further guidance in clinical, educational, and administrative applications. By implementing these recommendations, healthcare institutions can better leverage the skills and leadership capacity of nurses to achieve safer, more effective infection control in hemodialysis care.

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