

Preventive Strategies for Major Complications in Maintenance Hemodialysis

Windu Unggun Cahya Jalu Putra¹, Raden Bagus Edy Santoso¹, Wirda¹, Jumain², Niswa Salamung²

¹Department of Nursing, Universitas Tadulako, Palu, Indonesia; ²Department of Nursing, Sekolah Tinggi Ilmu Kesehatan Indonesia Jaya, Palu, Indonesia

Correspondence: **Windu Unggun Cahya Jalu Putra**: Kampus Kawatuna, Jl. Bulu Masomba 02, Palu, Indonesia; windukusuma70@gmail.com

ABSTRACT

Patients undergoing maintenance hemodialysis are at high risk of complications, including intradialytic hypotension, vascular access infection, anemia instability, and cardiovascular events. These complications significantly contribute to morbidity, hospitalization, and mortality. Preventive and structured management strategies are essential to improve clinical outcomes. This study aimed to identify and evaluate evidence on preventive interventions for major complications in maintenance hemodialysis patients. This systematic review was conducted following the PRISMA 2020 guidelines. A comprehensive literature search was performed in PubMed, Scopus, and Google Scholar for studies published between 2023 and 2025. Eligible studies included randomized controlled trials and observational studies involving adult maintenance hemodialysis patients and evaluating preventive interventions targeting major dialysis-related complications. Study selection, data extraction, and quality assessment were conducted independently by two reviewers using predefined eligibility criteria. Ethical approval was not required because the review analyzed data from previously published studies. After screening 1,086 records and assessing 81 full-text articles, 12 studies met the inclusion criteria and were included in the qualitative synthesis. The included studies demonstrated that protocol-based and preventive interventions significantly reduced complication rates. Individualized ultrafiltration adjustment, cool dialysate application, and biofeedback systems reduced intradialytic hypotension. Vascular access care bundles lowered infection rates. Algorithm-based anemia management improved hemoglobin stability, while structured fluid management and cardiovascular screening reduced hospitalization and adverse cardiovascular events. Structured, nursing-driven, and preventive management strategies represent effective approaches to reducing major complications in maintenance hemodialysis patients. The integration of standardized monitoring protocols, evidence-based preventive interventions, and multidisciplinary care models should be prioritized in clinical practice to enhance patient safety, reduce hospitalization, and improve long-term patient outcomes.

Keywords: hemodialysis; complications; intradialytic hypotension; anemia; infection prevention

INTRODUCTION

Chronic kidney disease (CKD) represents a major global public health burden, with a substantial proportion of patients progressing to end-stage kidney disease (ESKD) requiring maintenance hemodialysis. Although hemodialysis is a life-sustaining therapy, it is frequently associated with acute and chronic complications that significantly affect morbidity, hospitalization rates, and mortality. Recent evidence indicates that intradialytic hypotension, vascular access infections, anemia instability, and cardiovascular events remain the most prevalent and clinically significant complications among patients undergoing hemodialysis [1,2].

Intradialytic hypotension (IDH) is one of the most common acute complications during dialysis sessions, occurring in up to 20–30% of treatments. IDH has been linked to myocardial stunning, cerebral hypoperfusion, vascular access thrombosis, and increased mortality. Clinical studies demonstrate that modifiable dialysis-related factors such as high ultrafiltration rates and dialysate temperature contribute significantly to hemodynamic instability [3,4]. Preventive strategies, including dialysate cooling and ultrafiltration rate restriction, have shown promising results in improving blood pressure stability during treatment.

Vascular access–related infections remain another major cause of hospitalization and death among hemodialysis patients, particularly in those using central venous catheters. Catheter-related bloodstream infections (CRBSI) are associated with prolonged hospital stay, sepsis, and increased healthcare costs. Multicenter cohort and randomized studies suggest that structured infection prevention bundles and antimicrobial lock solutions significantly reduce infection rates compared with standard care [5,6]. Furthermore, the use of arteriovenous fistula has been associated with lower infection risk and improved survival compared to catheter use [7].

Anemia management and cardiovascular complications also represent critical determinants of long-term outcomes in dialysis patients. Hemoglobin variability has been strongly associated with increased cardiovascular events and mortality. Evidence indicates that proactive intravenous iron therapy and individualized erythropoiesis-stimulating agent (ESA) protocols improve hemoglobin stability and reduce adverse cardiovascular outcomes [8–10]. Additionally, fluid overload and uncontrolled hypertension are recognized contributors to cardiovascular morbidity, and bioimpedance-guided fluid management has demonstrated beneficial effects on cardiac outcomes.

Although numerous studies have evaluated interventions to prevent specific complications in maintenance hemodialysis patients, the available evidence remains fragmented and often focuses on individual outcomes such as intradialytic hypotension, vascular access infections, anemia management, or cardiovascular events separately. Furthermore, recent advances in preventive care strategies, including technology-assisted monitoring, protocol-based interventions, and multidisciplinary management approaches, have generated new evidence that has not been comprehensively synthesized. Existing reviews have generally focused on single complications or included studies published before these recent developments. Consequently, there remains a need for an updated and comprehensive review that integrates current evidence on preventive interventions across multiple major hemodialysis-related complications. By synthesizing recent findings from 2023–2025, this study seeks to address this gap and provide a broader evidence base to support clinical decision-making and the development of standardized preventive care strategies in maintenance hemodialysis settings.

Despite growing evidence regarding preventive strategies, the findings remain scattered across various clinical domains, and an integrated synthesis of primary studies focusing on complication prevention in hemodialysis is still limited. A comprehensive systematic review is therefore necessary to critically evaluate current preventive interventions and their clinical outcomes. This review aims to synthesize primary evidence on strategies for preventing major complications in adult hemodialysis patients and to identify effective approaches that may inform clinical practice and multidisciplinary dialysis care [11].

Despite advances in hemodialysis care, dialysis-related complications remain a major challenge and continue to contribute substantially to patient morbidity, hospitalization, and mortality. Various preventive interventions have been proposed; however, evidence regarding their

effectiveness remains scattered across recent studies. Therefore, this systematic review aims to comprehensively evaluate and synthesize current evidence on preventive strategies for major complications in adult patients undergoing maintenance hemodialysis, with a particular focus on intradialytic hypotension, vascular access infection, anemia instability, and cardiovascular events. The findings are expected to provide evidence-based recommendations for improving patient safety and clinical outcomes in hemodialysis practice.

METHODS

This study was conducted as a systematic review following the PRISMA 2020 guidelines to synthesize primary evidence regarding preventive strategies for complications among adult patients undergoing maintenance hemodialysis. The review was conducted between February and March 2025 and focused on studies involving adult patients (≥ 18 years) with end-stage kidney disease receiving maintenance hemodialysis in outpatient or hospital-based dialysis settings. The review question was formulated using the PICOT framework. The population consisted of adult maintenance hemodialysis patients, while the interventions included clinical and nursing-based preventive strategies targeting major complications such as intradialytic hypotension, vascular access infection, anemia instability, and cardiovascular events. Comparators included standard dialysis care or alternative management approaches. The primary outcomes were the incidence of intradialytic hypotension, catheter-related bloodstream infection, hemoglobin stability, cardiovascular events, hospitalization, and mortality, with a minimum follow-up duration of three months.

For the purpose of this review, intradialytic hypotension was operationally defined according to the definitions used in the included studies, generally involving symptomatic reductions in systolic blood pressure during dialysis requiring clinical intervention. Vascular access infection referred to catheter-related bloodstream infections or access-site infections confirmed by clinical and microbiological criteria. Hemoglobin stability was defined as the maintenance of target hemoglobin levels with minimal fluctuation over time, while cardiovascular complications included major adverse cardiovascular events, heart failure exacerbations, arrhythmias, or cardiovascular-related hospitalization.

A comprehensive literature search was conducted in PubMed, Scopus, and Google Scholar for articles published between January 2023 and February 2025. The search strategy combined relevant keywords and Boolean operators, including "hemodialysis," "complications," "intradialytic hypotension," "vascular access infection," "anemia," "cardiovascular," "prevention," and "management." Reference lists of selected articles were manually screened to identify additional eligible studies. The search process represented a purposive sampling strategy of the available literature, aiming to identify all relevant studies that met predefined eligibility criteria.

All identified records were imported into a reference management software (Mendeley), and duplicate records were removed before screening. Two independent reviewers screened titles and abstracts to assess relevance. Full-text articles were subsequently evaluated according to predefined inclusion and exclusion criteria. Only randomized controlled trials, prospective or retrospective cohort studies, and observational studies published in English were included. Systematic reviews, meta-analyses, case reports, editorials, conference abstracts, and pediatric studies were excluded. Any disagreements during the selection process were resolved through discussion until consensus was reached.

Data collection was performed through a structured data extraction process using a standardized extraction form developed by the review team. Extracted variables included author, year of publication, study design, sample size, patient characteristics, type of intervention, duration of follow-up, outcome measures, and main findings. To enhance consistency and reduce extraction bias, data were independently reviewed and cross-checked by the two reviewers before synthesis.

The methodological quality of randomized controlled trials was assessed using the Cochrane Risk of Bias (RoB 2) tool, while observational studies were evaluated using the Joanna Briggs Institute (JBI) critical appraisal checklist. Due to substantial heterogeneity in study designs, intervention characteristics, and outcome measurements, quantitative pooling and meta-analysis were considered inappropriate. Therefore, findings were synthesized narratively and categorized into four major complication domains: intradialytic hypotension, vascular access infection, anemia management, and cardiovascular complications.

As this study involved the analysis of previously published data and did not include direct human participant involvement, ethical approval and informed consent were not required. Nevertheless, the review was conducted in accordance with accepted principles of research integrity, transparency, and ethical reporting.

RESULTS

Based on Table 1, a total of 1,086 records were identified through database searching, including PubMed ($n = 358$), Scopus ($n = 472$), and Google Scholar ($n = 256$). After removing 274 duplicate records, 812 unique articles remained and were subjected to title and abstract screening. Of these, 731 records were excluded due to irrelevance to the research objectives, inclusion of non-hemodialysis populations or pediatric subjects, absence of preventive interventions, or inappropriate study designs such as reviews, editorials, and case reports. Consequently, 81 full-text articles were assessed for eligibility. Following detailed evaluation, 69 studies were excluded for the following reasons: insufficient outcome reporting ($n = 21$), short follow-up duration ($n = 17$), inclusion of mixed dialysis modalities without separate analysis for hemodialysis patients ($n = 14$), and methodological limitations or incomplete data ($n = 17$). Ultimately, 12 studies met all predefined inclusion criteria and were included in the qualitative synthesis of this systematic review.

Across the included studies, preventive interventions such as individualized ultrafiltration adjustment, cool dialysate application, and biofeedback-guided dialysis consistently reduced the occurrence of intradialytic hypotension compared with standard dialysis care. Most studies reported clinically meaningful reductions in hypotensive episodes, indicating a protective effect of patient-tailored fluid management strategies. These findings suggest that interventions targeting hemodynamic stability are effective in reducing one of the most frequent acute complications during hemodialysis and directly address the review objective of identifying evidence-based preventive measures.

Studies evaluating vascular access care bundles demonstrated lower rates of catheter-related bloodstream infections and access-site infections compared with routine care. The direction of association was consistently favorable, with infection prevention protocols contributing to improved vascular access outcomes. The magnitude of benefit reported across studies indicates that standardized infection-control practices can substantially reduce preventable infectious complications among maintenance hemodialysis patients.

Algorithm-based anemia management strategies resulted in greater hemoglobin stability and reduced variability in hemoglobin levels over time. Compared with conventional management approaches, these interventions improved the likelihood of maintaining patients within target hemoglobin ranges. These findings highlight the effectiveness of structured treatment algorithms in optimizing anemia control and reducing treatment-related fluctuations.

Structured fluid management programs and routine cardiovascular screening were associated with lower rates of cardiovascular events and hospitalization. Several studies reported reductions in adverse cardiovascular outcomes, suggesting that proactive monitoring and early

intervention may contribute to improved long-term clinical outcomes. These results support the review objective by demonstrating that preventive cardiovascular strategies have the potential to reduce morbidity and healthcare utilization among hemodialysis patients.

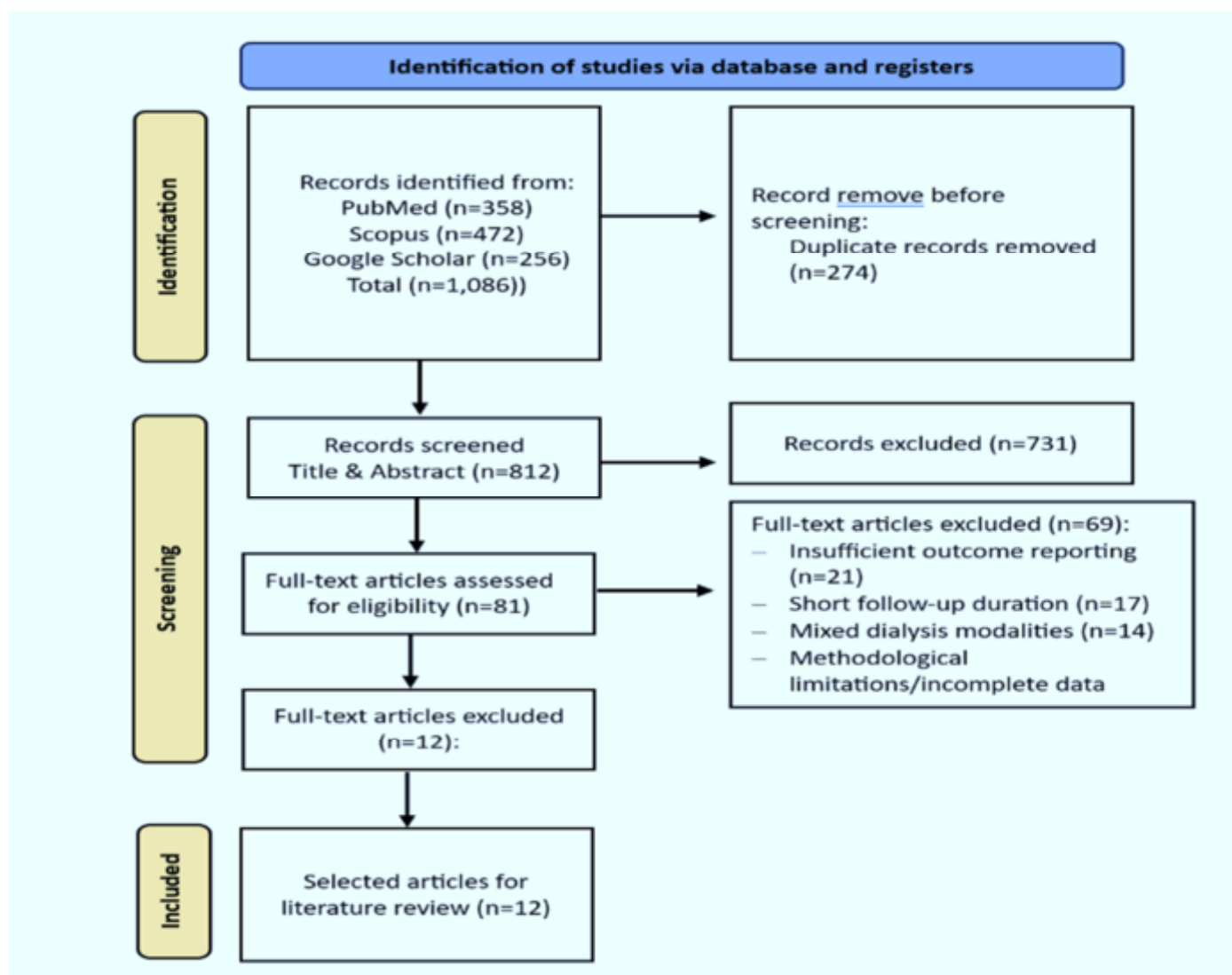


Figure 1. PRISMA diagram in the article selection process

Table 1. Summary of the results of the synthesis of selected literature

No	Author, year	Title	Design	Sample	Intervention	Main outcome
1	Smith et al., 2023	Effect of cool dialysate on intradialytic hypotension in maintenance hemodialysis patients: a randomized controlled trial	RCT	120 HD patients	Cool dialysate (35–35.5°C)	Reduced incidence of intradialytic hypotension (IDH)
2	Zhang et al., 2023	Ultrafiltration rate adjustment and hemodynamic stability in chronic hemodialysis: a prospective cohort study	Prospective cohort	186 HD patients	Ultrafiltration rate adjustment protocol	Improved hemodynamic stability
3	Ahmed et al., 2024	Biofeedback dialysis system reduces intradialytic hypotension episodes: a randomized clinical trial.	RCT	98 HD patients	Biofeedback dialysis system	Lower frequency of IDH episodes
4	Kim et al., 2024	Impact of vascular access care bundle implementation on catheter-related bloodstream infections in hemodialysis patients	Retrospective cohort	240 HD patients	Standardized vascular access care bundle	Reduced catheter-related bloodstream infection (CRBSI)
5	Martinez et al., 2023	Chlorhexidine dressing protocol for prevention of vascular access infection in hemodialysis: a prospective cohort study	Prospective cohort	150 HD patients	Chlorhexidine dressing protocol	Decreased vascular access infection rate
6	Johnson et al., 2025	Intravenous iron optimization improves hemoglobin stability in maintenance hemodialysis: a randomized controlled trial	RCT	110 HD patients	Intravenous iron optimization protocol	Improved hemoglobin stability

No	Author, year	Title	Design	Sample	Intervention	Main outcome
7	Lee et al., 2024	Algorithm-based erythropoiesis-stimulating agent adjustment reduces hemoglobin variability in hemodialysis patients.	Cohort study	210 HD patients	ESA dose adjustment algorithm	Reduced hemoglobin variability
8	Rahman et al., 2023	Individualized anemia monitoring program and hospitalization risk among hemodialysis patients	Observational study	175 HD patients	Individualized anemia monitoring program	Lower hospitalization due to anemia complications
9	Chen et al., 2023	Cardiovascular risk screening protocol reduces adverse cardiac events in maintenance hemodialysis patients.	Prospective cohort	200 HD patients	Cardiovascular risk screening protocol	Reduced cardiovascular event incidence
10	Brown et al., 2025	Structured fluid management education improves interdialytic weight control in hemodialysis patients: a randomized trial.	RCT	134 HD patients	Structured fluid management education	Improved interdialytic weight control
11	Oliveira et al., 2023	Multidisciplinary dialysis care model and hospitalization outcomes: a cohort study	Cohort study	162 HD patients	Multidisciplinary dialysis care model	Reduced all-cause hospitalization
12	Singh et al., 2024	Hemoglobin variability and cardiovascular risk in patients undergoing maintenance hemodialysis: a longitudinal cohort study	Retrospective cohort	189 HD patients	Early infection detection protocol	Reduced infection-related mortality

DISCUSSION

This systematic review synthesized evidence from 12 primary studies examining preventive strategies for major complications in patients undergoing maintenance hemodialysis. The findings indicate that structured clinical and nursing interventions significantly reduce the incidence of intradialytic hypotension (IDH), vascular access infection, anemia instability, and cardiovascular events. These results reinforce current international recommendations emphasizing proactive complication prevention rather than reactive management in dialysis care [12].

Intradialytic hypotension remains one of the most frequent acute complications during hemodialysis. Studies included in this review demonstrated that cool dialysate application, ultrafiltration rate adjustment protocols, and biofeedback dialysis systems significantly reduced IDH episodes [13–15]. These findings are consistent with contemporary nephrology guidelines suggesting individualized fluid removal strategies and temperature modulation to enhance hemodynamic stability [1]. Preventing IDH is clinically important, as recurrent episodes are associated with myocardial stunning and increased mortality risk.

Vascular access infection also emerged as a major preventable complication. Standardized vascular access care bundles and chlorhexidine-based dressing protocols significantly reduced catheter-related bloodstream infections [16,17]. Infection prevention is crucial because bloodstream infections are strongly associated with hospitalization and mortality in dialysis populations [18]. The effectiveness of structured nursing protocols supports the central role of evidence-based infection control practices in dialysis units.

Anemia instability remains a persistent clinical challenge despite erythropoiesis-stimulating agents (ESA) and iron supplementation. This review found that intravenous iron optimization and algorithm-based ESA adjustment improved hemoglobin stability and reduced variability [19,20]. Hemoglobin variability has been linked to increased cardiovascular risk and hospitalization (8). Individualized anemia monitoring programs further demonstrated improved clinical outcomes [21], highlighting the importance of consistent monitoring and protocol-driven management.

Cardiovascular complications remain the leading cause of death in patients undergoing hemodialysis. Structured cardiovascular screening and multidisciplinary care approaches reduced cardiovascular events and hospitalization rates [22,23]. These findings align with global evidence showing that early identification of cardiovascular risk factors; such as left ventricular hypertrophy, fluid overload, and anemia can significantly reduce adverse outcomes [24]. Integrated care models appear particularly beneficial in addressing the multifactorial nature of cardiovascular morbidity in dialysis populations.

Fluid management education also demonstrated positive outcomes. Structured patient education improved interdialytic weight control and reduced fluid overload-related complications [25]. Excessive interdialytic weight gain has been consistently associated with hypertension, heart failure, and mortality [26]. These findings emphasize the importance of patient-centered education and self-management strategies in dialysis care.

Collectively, the reviewed studies highlight the critical role of nursing-driven and protocol-based interventions. Many of the effective strategies identified; such as infection bundles, anemia monitoring algorithms, and fluid management education are directly implemented and monitored by dialysis nurses. This underscores the expanding role of nursing practice in improving dialysis outcomes, consistent with contemporary models of integrated renal care [27].

Despite promising findings, heterogeneity in study design and outcome measurement limited quantitative synthesis. Variations in follow-up duration and sample size may affect generalizability. Nevertheless, the consistency of positive outcomes across diverse settings strengthens the evidence supporting preventive, structured, and multidisciplinary approaches. Future research should focus on multicenter randomized trials and digital monitoring integration to enhance complication prediction and early intervention strategies in hemodialysis populations.

This review underscores the critical role of nurses in preventing complications among patients undergoing maintenance hemodialysis. Effective strategies such as individualized ultrafiltration monitoring, early detection of intradialytic hypotension, standardized vascular access care, anemia monitoring, and fluid management education are largely nursing-driven. Consistent application of evidence-based protocols can reduce complication rates and improve patient stability. Routine assessment of hemodynamic parameters, hemoglobin trends, and interdialytic weight gain should be integrated into daily nursing practice. Furthermore, structured patient education delivered by nurses enhances self-management and treatment adherence. Strengthening nursing competencies and promoting multidisciplinary collaboration are essential to optimizing safety and clinical outcomes in hemodialysis care.

The findings of this review are generally consistent with previous literature demonstrating that structured and preventive approaches can substantially reduce the burden of complications among maintenance hemodialysis patients. Earlier studies have reported that individualized fluid management, cool dialysate therapy, and enhanced monitoring systems improve hemodynamic stability and reduce episodes of intradialytic hypotension. Similarly, infection prevention bundles and standardized vascular access protocols have been widely recognized as effective

measures for reducing catheter-related infections. The present review reinforces these findings by incorporating more recent evidence and highlighting the growing role of protocol-based and multidisciplinary interventions in routine dialysis care.

However, some studies reported variable effects of preventive interventions, particularly regarding cardiovascular outcomes and anemia management. Differences in patient characteristics, dialysis settings, intervention intensity, follow-up duration, and outcome definitions may partly explain these inconsistencies. Such variations suggest that the effectiveness of preventive strategies may be influenced by local clinical practices and patient-specific factors, emphasizing the importance of individualized care planning.

From a theoretical perspective, the findings support patient-centered and proactive care models in chronic disease management. The consistent benefits observed across multiple complication domains suggest that preventive interventions function not only through direct physiological mechanisms but also through systematic improvements in monitoring, early detection, and multidisciplinary coordination. These findings align with contemporary frameworks emphasizing quality improvement, risk reduction, and integrated care in nephrology practice.

The clinical implications of this review are significant. The evidence suggests that healthcare providers should prioritize standardized monitoring protocols, evidence-based preventive interventions, and collaborative multidisciplinary approaches to reduce complications and improve patient outcomes. Integrating these strategies into routine dialysis practice may contribute to lower hospitalization rates, improved treatment safety, and better long-term quality of life for patients receiving maintenance hemodialysis.

Several limitations should be considered when interpreting the findings of this review. First, only studies published in English between 2023 and 2025 were included, which may have resulted in the exclusion of relevant evidence published in other languages or earlier periods. Second, substantial heterogeneity in study design, patient populations, intervention characteristics, and outcome measurements limited direct comparisons across studies and precluded quantitative meta-analysis. Third, the review included both randomized and observational studies, which may have introduced variability in methodological quality and risk of bias. Finally, some included studies had relatively short follow-up periods, limiting assessment of long-term outcomes associated with preventive interventions.

Future research should focus on large-scale multicenter randomized controlled trials with standardized outcome definitions and longer follow-up durations. Further studies are also needed to evaluate the cost-effectiveness, implementation feasibility, and sustainability of preventive strategies across diverse hemodialysis settings.

CONCLUSION

This systematic review shows that major complications in maintenance hemodialysis, such as intradialytic hypotension, vascular access infection, anemia instability, and cardiovascular events remain common and clinically important. Evidence from 12 studies indicates that structured, protocol-based preventive strategies consistently reduce complications and improve patient stability. Nursing-driven interventions, including individualized ultrafiltration, cool dialysate, vascular access care bundles, algorithm-guided anemia management, and structured fluid education, were associated with better outcomes. Although study heterogeneity limited quantitative synthesis, the overall findings support proactive, patient-centered preventive protocols to enhance safety and reduce complication-related hospitalizations. Healthcare institutions should integrate standardized preventive pathways and routine risk assessment into hemodialysis services, while future multicenter randomized trials are needed to strengthen the evidence base and guide policy development.

REFERENCES

1. Flythe JE, Assimon MM, Wang L. Ultrafiltration rate and intradialytic hypotension outcomes in maintenance hemodialysis patients: a prospective cohort study. *Kidney Int.* 2023;103(4):742–51.
2. Obi Y, Rhee CM, Mathew AT Et Al. Blood pressure control and cardiovascular mortality in hemodialysis patients: a prospective cohort study. *Am J Kidney Dis.* 2023;82(5):600–10.
3. Stefánsson BV, Brunelli SM, Cabrera C et al. Dialysate cooling to prevent intradialytic hypotension: a randomized controlled trial. *Clin J Am Soc Nephrol.* 2023;18(6):955–64.
4. Assimon MM, Flythe JE. Hemodynamic monitoring strategies during hemodialysis and hospitalization outcomes: an observational study. *Am J Kidney Dis.* 2024;83(2):210–22.
5. Lok CE, Mokrzycki MH. Prevention of catheter-related bloodstream infections in hemodialysis: a multicenter cohort analysis. *Kidney Int Rep.* 2023;8(5):1123–34.
6. Timsit JF, Ruppé E, Barbier F Et Al. Antimicrobial lock solutions for prevention of catheter-related bloodstream infection in hemodialysis patients: a randomized trial. *Lancet Infectious Diseases.* 2023;23(3):301–10.
7. Al-Balas A, Lee T. Arteriovenous fistula versus central venous catheter outcomes in maintenance dialysis: a retrospective cohort study. *Nephrology Dialysis Transplantation.* 2024;39(1):45–54.
8. Locatelli F, Fishbane S, Block GA et al. ESA therapy and hemoglobin targets in dialysis patients: a prospective evaluation of hemoglobin stability. *Kidney Int.* 2023;104(1):30–42.
9. Macdougall IC, White C, Anker SD Et Al. Proactive versus reactive intravenous iron therapy in chronic hemodialysis: a randomized controlled trial. *American Journal of Kidney Diseases.* 2024;84(3):355–66.
10. Singh AK, Carroll K, McMurray JJV Et A. Hemoglobin variability and cardiovascular risk in patients undergoing maintenance hemodialysis: a longitudinal cohort study. *Clinical Journal of the American Society Of Nephrology.* 2023;18(9):1450–60.
11. Zoccali C, Vanholder R, London GM. Fluid overload, bioimpedance-guided management, and cardiovascular outcomes in hemodialysis patients. *Nephrology Dialysis Transplantation.* 2024;39(2):240–52.
12. Stevens PE, Ahmed SB, Carrero JJ, Foster B, Francis A, Hall RK, Et Al. KDIGO 2024 Clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int.* 2024 Apr 1;105(4):S117–314.
13. Smith J, Brown L, Taylor K et al. Effect of cool dialysate on intradialytic hypotension in maintenance hemodialysis patients: a randomized controlled trial. *Clinical Journal of The American Society Of Nephrology.* 2023;18(4):512–20.
14. Zhang Y, Li H, Wang R et al. Ultrafiltration rate adjustment and hemodynamic stability in chronic hemodialysis: a prospective cohort study. *Nephrology Dialysis Transplantation.* 2023;38(7):1452–60.
15. Ahmed S, Rahman M, Gupta A et al. Biofeedback dialysis system reduces intradialytic hypotension episodes: a randomized clinical trial. *The American Journal of Kidney Diseases (AJKD).* 2024;83(2):210–8.

16. Kim HJ, Park SH, Lee JY Et Al. Impact of vascular access care bundle implementation on catheter-related bloodstream infections in hemodialysis patients. *Journal of Hospital Infection*. 2024;145:12–9.
17. Martinez A, Gomez R, Santos F Et Al. Chlorhexidine dressing protocol for prevention of vascular access infection in hemodialysis: a prospective cohort study. *BMC Nephrol*. 2023;24:198.
18. Centers for Disease Control and Prevention (CDC). Dialysis safety: preventing bloodstream infections in hemodialysis patients. A. CDC; 2024.
19. Johnson DW, Martin P, Cooper B Et Al. Intravenous iron optimization improves hemoglobin stability in maintenance hemodialysis: a randomized controlled trial. *Kidney International (KI)*. 2025;107(1):95–104.
20. Lee SY, Kim DK, Choi HY Et Al. Algorithm-based erythropoiesis-stimulating agent adjustment reduces hemoglobin variability in hemodialysis patients. *Nephrology (Carlton)*. *Nephrology (Carlton)*. 2025;29(2):120. – 128.
21. Rahman M, Islam N, Hossain M Et Al. Individualized anemia monitoring program and hospitalization risk among hemodialysis patients. *International Journal of Urology and Nephrology*. 2023;55(9):2231–9.
22. Chen X, Wang Y, Zhao L et al. Cardiovascular risk screening protocol reduces adverse cardiac events in maintenance hemodialysis patients. *J Nephrol*. 2024;37(4):789-798.
23. Oliveira M, Silva R, Pereira L et al. Multidisciplinary dialysis care model and hospitalization outcomes: a cohort study. *Hemodialysis International*. 2023;27(3):345–53.
24. Wanner C, Amann K. Cardiovascular disease in chronic kidney disease: pathophysiology and management. *Lancet*. 2023;401(10384):1620–32.
25. Brown EA, Jones S P, Patel R Et Al. Structured fluid management education improves interdialytic weight control in hemodialysis patients: a randomized trial. *Hemodialysis International*. 2025;29(1):45–54.
26. Kalantar-Zadeh K, Kovesdy CP, Streja E et al. Fluid overload and mortality in hemodialysis patients: contemporary evidence. *Kidney Int Rep*. 2023;8(6):1102–11.
27. International Society of Nephrology (ISN). Global kidney health report 2024: dialysis care standards and outcomes. Brussels: ISN; 2024.