The Impact of Nurse-Led Continuous Renal Replacement Therapy Management on Clinical Outcomes in Adult Critically Ill Patients: A Systematic Review

Nooshin Dalili,[1] Behraz Alipoorabedi,[2] Nnaemezie Odioemene,[2] Behnam Hoshyaripour,[3] Behrang Alipour Abedi[4]

[1]Nephrology Department, Dr.Labbafinezhad Medical Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Cobb Nephrology and Hypertension Associate, Austell, GA, USA
[3]CEO of Pars Hiva Darou Company, Member of the Board of Directors of Hiva Chemical Industry Research Center, Tehran, Iran
[4]Shahid Beheshti University of Medical Sciences, Tehran, Iran

Introduction. Continuous renal replacement therapy (CRRT) is a cornerstone treatment for hemodynamically unstable critically ill patients with acute kidney injury (AKI). Despite technological advances, CRRT outcomes remain variable, and the impact of nursing leadership in CRRT delivery has not been sufficiently synthesized. This study aims to evaluate the effect of nurse-led CRRT management on clinical and treatment-related outcomes in adult critically ill patients.

Methods. A systematic review was conducted according to PRISMA 2020 guidelines. PubMed/MEDLINE, Embase, Scopus, CINAHL, and the Cochrane Library were searched for studies involving adult ICU patients receiving CRRT where nurse-led management was explicitly described. Primary outcomes included mortality, circuit lifespan, and unplanned circuit interruption or clotting. Secondary outcomes included delivered CRRT dose, treatment downtime, and CRRT-related complications.

Results. Fifteen eligible studies were identified, including randomized and non-randomized designs evaluating nurse-led CRRT models compared with standard or physician-led care. Nurse-led CRRT management was associated with prolonged circuit lifespan and reduced unplanned interruptions in most studies. Mortality effects were variable. Heterogeneity across studies reflected differences in staffing models, protocols, and outcome definitions.

Conclusions. Nurse-led CRRT management appears to improve key treatment-related outcomes and care continuity in adult ICU patients. These findings have important implications for workforce development and care models, particularly in low- and middle-income countries (LMICs).

INTRODUCTION

Acute kidney injury (AKI) is a prevalent and severe complication among patients in intensive care units (ICUs), affecting 40 to 60% of this population. AKI significantly increases morbidity, mortality, hospital length of stay, and healthcare expenditures.[1-3] In patients with severe AKI and hemodynamic instability, continuous renal

replacement therapy (CRRT) is the preferred modality for renal support. CRRT facilitates gradual solute clearance and fluid removal, thereby minimizing abrupt intravascular volume shifts and cardiovascular stress compared to intermittent hemodialysis.[4-7]

Despite advancements in CRRT technology, membranes, and anticoagulation strategies, patient outcomes remain highly variable.[2,4-6] Suboptimal outcomes are often attributable to operational factors rather than device limitations. These include frequent treatment interruptions, premature circuit clotting, inadequate anticoagulation management, and failure to deliver the prescribed dialysis dose-all of which compromise efficacy and contribute to adverse clinical outcomes.[8-11]

Nursing practice is central to the delivery and success of CRRT.[8-10] Nurses manage continuous bedside operations, including vascular access surveillance, circuit monitoring, anticoagulation titration, and alarm troubleshooting. Given the continuous nature of CRRT, nursing competence and vigilance directly influence circuit lifespan and therapeutic target achievement. Frequent interruptions and dose deviations are often linked to workflow inefficiencies that fall within the nursing domain.[1,8,11]

Consequently, nurse-led CRRT management models have emerged. In these models, specially trained critical care or nephrology nurses assume primary responsibility for CRRT operations within standardized protocols, often with consultative rather than continuous physician oversight. These approaches aim to enhance efficiency, prolong circuit lifespan, and optimize delivered doses while maintaining patient safety. While several observational studies have suggested benefits, findings have yet to be comprehensively synthesized.

The relevance of nurse-led CRRT is particularly pronounced in low- and middle-income countries (LMICs), where access to nephrology specialists may be limited. In such settings, empowering nurses through structured training and protocol-driven autonomy may represent a cost-effective and scalable strategy to improve patient outcomes.[13-5]

Despite growing interest, uncertainty remains regarding the impact of these models on clinical outcomes and safety. This systematic review aims to evaluate the effect of nurse-led CRRT management on clinical and treatment-related outcomes, with a focus on circuit lifespan, treatment continuity, delivered dose, and patient safety.[8-12]

MATERIALS AND METHODS
Protocol and Reporting
This review followed the Preferred Reporting Items for Systematic Reviews (PRISMA) 2020 guidelines. The protocol was developed a priori.

Eligibility Criteria
Study Designs. Randomized controlled trials (RCTs), prospective and retrospective cohort studies, and before-after interventional studies included. Reviews, editorials, case reports, and conference abstracts were excluded.

Population. Adult patients ($\geq$ 18 years) in ICUs receiving CRRT

Exposure. Nurse-led CRRT management (nurses holding primary responsibility for bedside management via institutional protocols).

- **Comparator:** Physician-led models, Mixed-management models, or Standard care
- **Outcomes:** Primary outcomes were mortality, circuit lifespan, and unplanned interruptions. Secondary outcomes included delivered dose, downtime, and complications.

Search Strategy
PubMed/MEDLINE, Embase, Scopus, CINAHL, and the Cochrane Library were searched for English-language studies using terms related to "CRRT," "critical care nursing," and "nurse-led management."

Data Extraction and Quality Assessment
Two reviewers independently screened titles and extracted data using standardized forms. Disagreements were resolved via consensus. Risk of bias for non-randomized studies was assessed using the ROBINS-I tool.

RESULTS
Of the 15 included studies, five directly evaluated nurse-led CRRT models. These studies consistently demonstrated improved circuit lifespan and reduced

unplanned interruptions. Mortality outcomes were inconsistently reported and could not be conclusively linked to the management model. (See Table 1 for study classifications).

Only Studies 8 to 12 directly evaluate nurse-led or nursing-driven CRRT management and outcomes (Table 1). The remaining studies provide contextual and mechanistic support, not primary outcome comparisons (Table 2).

Study Selection

The systematic database search identified 1,247 records. After removing 312 duplicates, 935 records were screened by title and abstract. Of these, 862 records were excluded for failing to meet the inclusion criteria. Seventy-three full-text articles were assessed for eligibility, of which 58 were excluded due to pediatric populations, absence of a nurse-led CRRT description, use of non-CRRT modalities, or insufficient outcome data (Figure). Ultimately, 15 eligible articles were included in the review.

Study Characteristics

The included studies varied in ICU settings, geographic locations, and specific nurse-led CRRT implementation models. Most studies assessed protocol-driven nursing management versus standard or physician-led care. Notably, although 15 studies were included in the overall review, only five (Studies 8 to 12) directly examined nurse-led or nursing-driven CRRT management and its specific impact on outcomes. The other studies offered essential contextual and mechanistic support rather than primary outcome comparisons.

Primary Outcomes

Nurse-led CRRT management was consistently associated with longer circuit lifespan and a reduction in unplanned interruptions. In contrast, mortality outcomes were inconsistently reported across the literature and demonstrated no uniform direction of effect (Table 3).
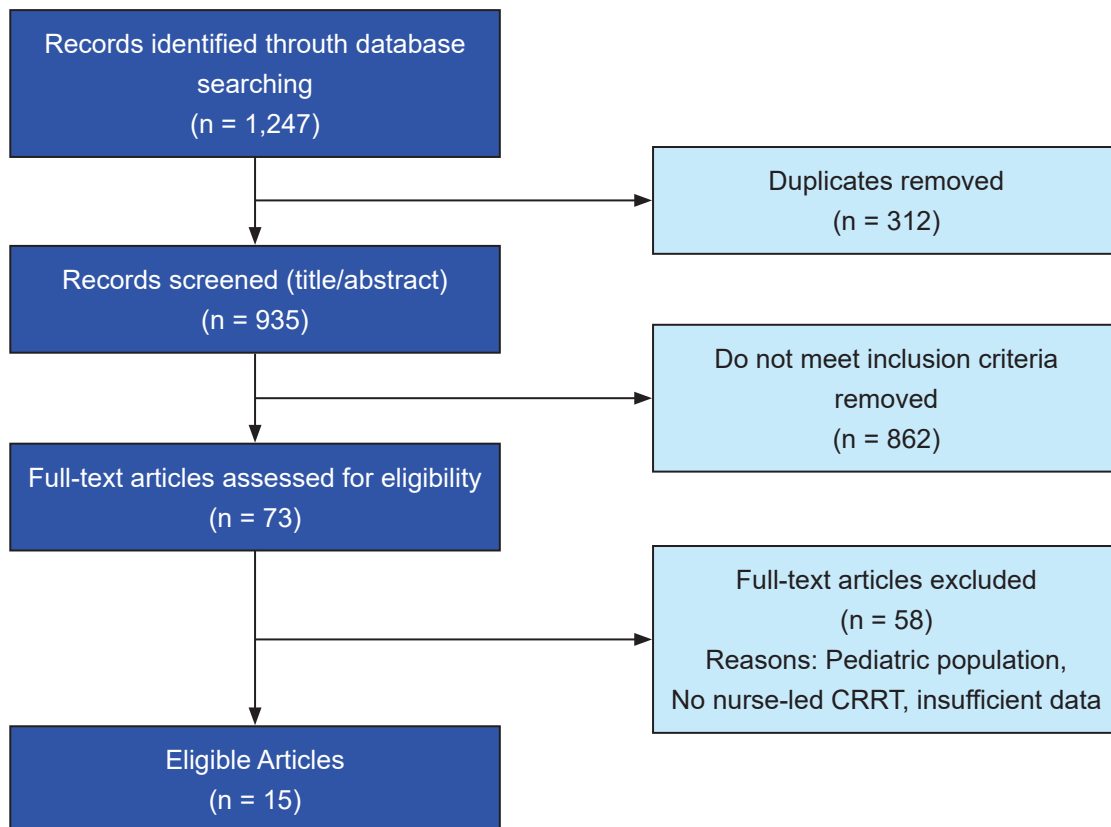
Nurse-led or nursing-intensive CRRT models

Table 1. Classification and Relevance of Included Studies (n = 15)

(Author, Year)	Study Type	Primary Relevance to Review Question
Kellum & Lameire, 2013[1]	Guideline	AKI context; CRRT indications
Hoste et al., 2015[2]	Epidemiological study	AKI burden in ICU
Bellomo et al., 2012[3]	Narrative review	AKI outcomes and CRRT role
Ronco et al., 2019[4]	Narrative review	CRRT principles
Ricci & Ronco, 2018[5]	Narrative review	Evolution of CRRT
Uchino et al., 2005[6]	Multicenter cohort	AKI outcomes; CRRT utilization
Tolwani, 2012[7]	Clinical review	CRRT implementation
Baldwin et al., 2007[8]	Multicenter observational	Nursing-based CRRT management
Mottes & Goldstein, 2018[9]	Nursing review	Nursing responsibilities in CRRT
Villa et al., 2016[10]	Observational / review	Nursing role & patient safety
Clark et al., 2014[11]	Observational cohort	Circuit lifespan & nursing practice
Vandijck et al., 2013[12]	Observational study	Nurse staffing/training impact
Tandukar & Palevsky, 2019[13]	Review	CRRT indications & delivery
Murugan et al., 2016[14]	Observational / review	CRRT fluid management
WHO, 2020[15]	Global report	Nursing workforce & training

Note. Only Studies 8 to 12 directly evaluate nurse-led or nursing-driven CRRT management and outcomes. The remaining studies provide contextual and mechanistic support, not primary outcome comparisons.

Table 2. Contextual Studies Supporting CRRT and Nursing Models (Non-Outcome)

Study	Key Contribution to Review
Kellum & Lameire, 2013[1]	Defines AKI severity guiding CRRT initiation
Bellomo et al., 2012[3]	Describes AKI morbidity and mortality
Ronco et al., 2019[4]	Establishes CRRT principles requiring bedside expertise
Ricci & Ronco, 2018[5]	Highlights complexity of CRRT delivery
Tolwani, 2012[7]	Emphasizes need for skilled CRRT management
Tandukar & Palevsky, 2019[13]	Reinforces protocol-based CRRT delivery
Murugan et al., 2016[14]	Demonstrates precision needs in CRRT
WHO, 2020[15]	Supports investment in nursing education and leadership

Records identified throuth database searching
(n = 1,247)

Duplicates removed
(n = 312)

Records screened (title/abstract)
(n = 935)

Do not meet inclusion criteria removed
(n = 862)

Full-text articles assessed for eligibility
(n = 73)

Full-text articles excluded
(n = 58)
Reasons: Pediatric population,
No nurse-led CRRT, insufficient data

Eligible Articles
(n = 15)

PRISMA 2020 Flow Diagram of Study Selection (Flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of studies evaluating nurse-led continuous renal replacement therapy management in adult critically ill patients. Records were identified through database searching, duplicates were removed, and studies were screened by title and abstract. Full-text articles were assessed for eligibility, with reasons for exclusion documented).

Table 3. Primary Outcomes Linked to Individual Studies

Study	Circuit Lifespan	Interruptions / Downtime	Mortality Outcomes	Contribution
Baldwin et al., 2007[8]	↑ Longer filter survival	↓ Unplanned interruptions	Not primary endpoint	Multicenter evidence of nursing-based CRRT management improving circuit performance
Clark et al., 2014[11]	↑ Prolonged circuit lifespan	↓ Premature clotting	No independent effect	Identified nursing practices as determinants of circuit longevity
Vandijck et al., 2013[12]	Indirect improvement	↓ Downtime	Not reported	Demonstrated impact of nurse staffing and training on CRRT delivery quality
Villa et al., 2016[10]	Not quantified	↓ Adverse events	Not reported	Linked nursing vigilance to patient safety
Mottes & Goldstein, 2018[9]	Conceptual	Conceptual	Not applicable	Synthesized nursing-specific CRRT responsibilities

are consistently associated with improved circuit performance, while the effects on mortality remain inconclusive or unmeasured.

Secondary Outcomes

Several studies reported improved delivered CRRT dose and reduced downtime with nurse-led models. Complication rates were comparable or reduced (Table 4).

DISCUSSION

This systematic review demonstrates that nurse-led CRRT management is associated with significant improvements in key treatment-related outcomes, particularly circuit lifespan and treatment continuity.[8,10-2] These findings highlight the pivotal role of nursing leadership in optimizing CRRT delivery and quality. Furthermore, they reinforce the concept that effective CRRT is highly dependent

Table 4. Secondary Outcomes by Study

Study	Delivered Dose	Complications	Safety / Quality Indicators
Baldwin et al., 2007[8]	↑ Dose consistency	↓ Filter clotting	Improved protocol adherence
Clark et al., 2014[11]	Indirect	↓ Clotting	Nursing technique influenced outcomes
Vandijck et al., 2013[12]	↑ Effective delivery	↓ Technical failures	Staffing adequacy critical
Villa et al., 2016[10]	Not reported	↓ Errors & alarms	Improved patient safety
Mottes & Goldstein, 2018[9]	Conceptual	Addressed	Education reduced adverse events

on bedside expertise and continuous clinical oversight, rather than solely on initial prescription parameters. By enhancing circuit performance and minimizing interruptions, nurse-led models ensure that the prescribed therapy dose is delivered more reliably—an essential factor for maintaining metabolic stability and fluid balance in critically ill patients.[4,7]

The observed benefits are likely attributable to the unique position of bedside nurses, whose constant presence enables continuous monitoring, early identification of circuit dysfunction, timely anticoagulation adjustments, and prompt troubleshooting of access-related issues.[9-11] These competencies are critical, as circuit clotting and unplanned downtime remain the primary limitations of CRRT, often leading to increased blood loss, higher costs, and reduced treatment efficiency.[4,11] Standardized, protocol-driven nurse-led approaches may also mitigate practice variability, which has been identified as a key contributor to adverse events and suboptimal CRRT delivery in intensive care settings.[5,9]

The implications of these findings are particularly significant for low- and middle-income countries (LMICs), where the scarcity of nephrologists and intensivists often necessitates a greater reliance on nursing staff for the delivery of complex therapies.[13-5] In such settings, nurse-led CRRT models represent a pragmatic and cost-effective strategy to expand access to renal support while maintaining safety and quality of care. Investment in specialized nursing education, competency-based training, and standardized protocols has the potential to reduce circuit wastage and optimize resource utilization.[12,15] Furthermore, empowering nurses through expanded roles and structured autonomy may enhance job satisfaction and workforce retention—factors critical to sustaining services in resource-constrained environments.[15]

Limitations

Several limitations of the current evidence must be acknowledged. The majority of included studies were observational, introducing risks of selection bias and residual confounding. Additionally, significant heterogeneity in study designs, CRRT modalities, anticoagulation strategies, and outcome definitions limited direct comparisons and precluded a quantitative meta-analysis.[8,10-2] Patient-centered outcomes—including mortality, renal recovery, and long-term kidney function—were inconsistently reported, restricting definitive conclusions regarding the downstream clinical impact of nurse-led management.[4,6]

CONCLUSIONS

Despite these limitations, the consistent treatment-related benefits observed across diverse settings support the value of nurse-led CRRT management as a core component of high-quality ICU renal support. Future research should prioritize prospective, multicenter studies with standardized outcome measures to evaluate the impact of nurse-led models on patient-centered outcomes, cost-effectiveness, and long-term renal recovery. From a clinical perspective, these findings support the integration of structured nurse-led programs that emphasize specialized training and protocol-driven autonomy. Rather than a substitute for physician expertise, nursing leadership should be positioned as an essential element of multidisciplinary, safe, and effective CRRT delivery. Nurse-led CRRT management seems to enhance important process-related outcomes in adult critically ill patients and offers a promising approach to improve care delivery. Future research should emphasize standardized outcome reporting and prospective assessment of nursing-led CRRT models.

ACKNOWLEDGMENTS

CONFLICT OF INTEREST

Behrang Alipour Abedi is a member of the editorial team of RJCCN. The author had no involvement in the peer-review or editorial decision-making process for this manuscript.

FUNDING

REFERENCES

1. Kellum JA, Lameire N. KDIGO AKI Guideline Work Group. Diagnosis, evaluation, and management of acute kidney injury: a KDIGO summary (Part 1). Kidney Int. 2013;83(5):779–85.

2. Hoste EAJ, Bagshaw SM, Bellomo R, Cely CM, Colman R, Cruz DN, et al. Epidemiology of acute kidney injury in critically ill patients: the multinational AKI-EPI study. Intensive Care Med. 2015;41(8):1411–23.

3. Bellomo R, Kellum JA, Ronco C. Acute kidney injury. Lancet. 2012;380(9843):756–66.

4. Ronco C, Bellomo R, Kellum JA. Continuous renal replacement therapy: principles and practice. Lancet. 2019;393(10179):111–24.

5. Ricci Z, Ronco C. Renal replacement therapy in critically ill patients: from intermittent hemodialysis to CRRT. Nat Rev Nephrol. 2018;14(5):303–15.

6. Uchino S, Kellum JA, Bellomo R, Doig GS, Morimatsu H, Morgera S, et al. Acute renal failure in critically ill patients: a multinational, multicenter study. JAMA. 2005;294(7):813–18.

7. Tolwani AJ. Continuous renal-replacement therapy for acute kidney injury. N Engl J Med. 2012;367(26):2505–14.

8. Baldwin I, Bellomo R, Naka T, Koch B. A multicenter evaluation of nursing-based CRRT management. Intensive Care Med. 2007;33(10):1791–7.

9. Mottes TA, Goldstein SL. Nursing considerations in continuous renal replacement therapy. Crit Care Nurs Clin North Am. 2018;30(4):447–60.

10. Villa G, Ricci Z, Romagnoli S. Nursing role in CRRT management and patient safety. Blood Purif. 2016;42(3):219–27.

11. Clark WR, Letteri JJ, Uchino S, Bellomo R. CRRT circuit lifespan and nursing practice: clinical determinants and outcomes. Clin J Am Soc Nephrol. 2014;9(6):1120–27.

12. Vandijck DM, Oeyen S, Decruyenaere JM. Impact of nurse staffing and training on CRRT delivery in the ICU. Int J Nurs Stud. 2013;50(5):695–703.

13. Tandukar S, Palevsky PM. Continuous renal replacement therapy: who, when, why, and how. Chest. 2019;155(3):626–38.

14. Murugan R, Hoste E, Mehta RL, Samoni S, Ding X, Rosner MH, et al. Precision fluid management in continuous renal replacement therapy. Blood Purif. 2016;42:266–78.

15. World Health Organization. State of the World's Nursing 2020: Investing in Education, Jobs and Leadership. Geneva: WHO; 2020.

Correspondence to:
Behrang Alipour Abedi, MD, PhD by Research
Shahid Beheshti University of Medical Sciences, Tehran, Iran
ORCID ID: 0000-0002-7780-2656
Cellphone: 0989123834394
E-mail: behrangalipourmd@gmail.com