



IDENTIFICATION AND ANALYSIS OF ROOT CAUSES OF ADVERSE EVENTS IN HAEMODIALYSIS UNITS: A QUALITY IMPROVEMENT PERSPECTIVE AT RURAL TERTIARY CARE TEACHING HOSPITAL

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ABSTRACT :

Background

Haemodialysis is a life-sustaining treatment for patients with chronic kidney disease and end-stage renal disease. However, the procedure involves extracorporeal circulation, vascular access, dialysis machines, fluid removal, anticoagulation, medication administration and continuous patient monitoring. These interacting clinical, technical and organizational components create multiple opportunities for adverse events. Root Cause Analysis (RCA) provides a structured approach for identifying underlying system-level contributors to adverse events and developing corrective and preventive interventions.

Aim

To identify and analyse the root causes of adverse events occurring in a haemodialysis unit and examine their implications for quality improvement and patient safety in a rural tertiary care teaching hospital.

Methodology

A quantitative, descriptive and analytical hospital-based study was conducted in the haemodialysis unit of a selected rural tertiary care teaching hospital in Ahilyanagar District, Maharashtra. The study included 100 haemodialysis patients/sessions as reported in the dissertation. Data were obtained through retrospective review of patient and dialysis records and adverse-event reports, together with prospective observation. Demographic and clinical information was collected using a structured data sheet. Root Cause Analysis was performed using Fishbone Diagram and 5 Whys techniques. Descriptive statistics and appropriate inferential statistical tests were applied using Excel and R software.

Results

The mean age of participants was 48±16 years and the study population was predominantly male. Secondary education and self-employment were the most frequently reported educational and occupational categories. Among the adverse events reported, manpower-related events constituted 48.5% (n=16), access-related problems 21.2% (n=7), hypotension 18.2% (n=6), bleeding 3.0% (n=1), and other events 9.1% (n=3). RCA identified manpower as the largest individual root-cause category, accounting for 44.4% (n=16), followed by machine-related causes at 13.9% (n=5) and management-related causes at 8.3% (n=3). Several events involved combinations of root-cause categories, demonstrating that adverse events frequently arose from interacting system factors. A statistically significant association was reported between haemoglobin group and occurrence of adverse events ($p=0.035$).

Conclusion

The study indicates that adverse events in haemodialysis are influenced by interconnected manpower, machine, method, material and management factors. RCA can provide a practical framework for converting individual adverse-event reports into system-level quality-improvement opportunities. In rural tertiary care settings, routine incident reporting, staff training, protocol adherence, equipment monitoring, clinical surveillance and periodic RCA meetings may strengthen patient safety.

Keywords: Haemodialysis; Adverse Events; Root Cause Analysis; Fishbone Diagram; 5 Whys; Patient Safety; Quality Improvement; Rural Hospital; Dialysis Safety.

1. Introduction

Haemodialysis is one of the principal renal replacement therapies for patients with advanced chronic kidney disease and end-stage renal disease. It sustains life by removing metabolic waste products and excess fluid from the circulation and by assisting in the correction of electrolyte and acid-base disturbances. The increasing burden of chronic kidney disease associated with diabetes, hypertension, cardiovascular disease and population ageing has resulted in a growing need for dialysis services.

Despite its therapeutic importance, haemodialysis is a complex healthcare process. Blood must be circulated through an extracorporeal circuit and dialyser, while vascular access, anticoagulation, dialysate preparation, ultrafiltration and patient monitoring must occur appropriately and simultaneously. The dissertation identifies vascular access, dialysis machines, dialysate systems, anticoagulation and continuous monitoring as important components of the dialysis process and potential points of failure.

Adverse events during haemodialysis range from relatively minor symptoms to potentially life-threatening complications. Intradialytic hypotension, muscle cramps, nausea, vomiting, headache, vascular-access complications, bleeding, infection, air embolism, haemolysis and medication-related errors have all been described as relevant safety concerns. Vascular-access problems such as thrombosis, stenosis, infection and needle dislodgement may compromise dialysis adequacy and patient safety.

The occurrence of adverse events should not automatically be interpreted as evidence of individual negligence. Modern patient-safety approaches emphasize that adverse events commonly arise from multiple interacting factors. Human performance may be influenced by workload, staffing, training, communication, equipment design, workflow and organizational conditions. Reason's systems-based approach and the work of Leape contributed to the movement away from an exclusively individual-blame model toward identification and modification of system vulnerabilities.

In this context, Root Cause Analysis is an important quality-improvement methodology. RCA attempts to move beyond the immediate manifestation of an adverse event and examine the circumstances that permitted it to occur. The process involves reconstructing what happened, identifying contributing factors, asking why the event occurred and developing corrective actions designed to reduce recurrence.

Two simple RCA tools used in the present study were the **Fishbone Diagram** and the **5 Whys technique**. The Fishbone Diagram organizes potential causes into domains such as manpower, methods, machines, materials, environment and management. The 5 Whys approach explores causal chains by repeatedly asking why a problem occurred until deeper contributing factors become apparent.

The importance of this approach is particularly relevant in rural healthcare institutions. Rural tertiary care hospitals may encounter constraints involving human resources, infrastructure, equipment availability, maintenance systems and access to specialized services. The dissertation identifies these circumstances as important contextual considerations for quality improvement in the selected rural teaching hospital.

Therefore, systematic identification of adverse events and their underlying causes can help transform isolated incidents into opportunities for organizational learning. Rather than asking only *"Who made the error?"*, RCA encourages healthcare teams to ask *"What conditions allowed the event to occur, and what can be changed to make recurrence less likely?"*

2. Rationale for Root Cause Analysis in Haemodialysis

Patients receiving haemodialysis are repeatedly exposed to a complex treatment environment. A patient may undergo hundreds of dialysis sessions over the course of chronic treatment. Consequently, even relatively infrequent failures can become important when viewed across a large number of treatment episodes.

The dissertation identifies several broad contributors to dialysis-related adverse events, including human errors, equipment problems, communication gaps and process failures. It also emphasizes that systematic identification of these factors can support corrective action and improve service quality.

RCA is particularly useful because an adverse event often represents the final manifestation of a chain of preceding weaknesses. For example, an access-related event may involve not only the immediate procedural problem but also patient assessment, staff workload, availability of appropriate materials, adherence to procedures and supervision. Similarly, a machine-related event may reflect maintenance schedules, equipment availability, staff competency and monitoring systems.

The RCA approach adopted in the dissertation recognizes six broad domains:

1. **Manpower**
2. **Methods**
3. **Machines**
4. **Materials**
5. **Environment**
6. **Management**

These categories provide a practical framework for multidisciplinary discussion and identification of improvement opportunities.

3. Study Setting and Methodology

3.1 Study setting

The study was conducted in the haemodialysis unit of a selected rural tertiary care teaching hospital in Ahilyanagar District, Maharashtra. The hospital

provides haemodialysis services to patients with chronic kidney disease and end-stage renal disease from rural and surrounding areas. The unit manages routine dialysis procedures as well as dialysis-related complications.

3.2 Study design

The investigation was a quantitative, descriptive and analytical hospital-based study designed to identify adverse events and analyse their root causes using structured RCA techniques.

3.3 Study population and sampling

The study population consisted of patients undergoing in-centre haemodialysis during the study period. Convenient sampling was adopted. The dissertation reports a sample of 100 haemodialysis patients/sessions.

3.4 Data collection

The study incorporated retrospective and prospective components. Patient records, dialysis records and adverse-event reports were reviewed, while adverse events occurring during dialysis sessions were prospectively observed and documented. Demographic and clinical variables included age, sex, comorbidities, vascular-access type, haemoglobin level and dialysis-related characteristics.

Four principal data-collection tools were used:

- Adverse Event Reporting Form
- Root Cause Analysis Form
- Audit Checklist
- Demographic Data Sheet

The RCA form specifically incorporated Fishbone Diagram and 5 Whys techniques.

The instruments were reviewed by experts in public health, nephrology and hospital management. A pilot study involving 20 haemodialysis patients was conducted before final data collection.

3.5 Ethical considerations

Institutional Review Committee approval was obtained under letter number PIMS/SPHSM/IRC/2026/449/23 dated 18 November 2025. The dissertation states that informed consent was obtained, participant confidentiality was maintained using anonymous codes, and participants were informed of their right to withdraw.

3.6 Statistical analysis

Data were entered and coded and analysed using Microsoft Excel and R software. Frequencies, percentages, means and standard deviations were used for descriptive analysis. Appropriate statistical tests were used to examine associations between selected variables and adverse-event occurrence. RCA findings were analysed using Fishbone Diagram and 5 Whys techniques.

4. Theoretical and Quality-Improvement Framework

The dissertation applies the **Donabedian Structure–Process–Outcome Model** as its theoretical framework.

Structure

Structure encompasses the resources and organizational characteristics of the dialysis unit, including infrastructure, machines, staffing, equipment, policies and available resources.

Process

Process refers to the activities through which care is delivered, including patient assessment, dialysis procedures, infection prevention, monitoring, communication and adherence to standard operating procedures.

Outcome

Outcome includes adverse events, complications, patient-safety outcomes and improvements resulting from quality interventions.

The model proposes that appropriate structural conditions support safer processes and that effective processes contribute to better outcomes.

The conceptual framework of the dissertation follows a logical pathway:

Patient and clinical characteristics → Adverse events → RCA using Fishbone and 5 Whys → Identification of root causes → Corrective and preventive actions → Quality improvement and enhanced patient safety.

This framework is particularly suitable for haemodialysis because adverse events can arise from the interaction of patient characteristics, clinical procedures, human factors, technical systems and organizational processes.

5. Results

5.1 Participant characteristics

The mean age of participants was **48±16 years**. Male and female participants had comparable mean ages, with no significant difference reported for age distribution ($p=0.40$). Secondary education was the most frequently observed educational level, accounting for 57% of participants. Education differed significantly according to gender ($p=0.011$).

Self-employment was the most frequently reported occupational category (69%), followed by unemployment (22%), with occupation also showing a significant gender association ($p<0.001$). Approximately 64% belonged to the upper-middle socioeconomic category. Equal proportions were reported to have AVF and other vascular-access methods.

The reported mean haemoglobin level was 10.30 ± 11.93 g/dL, while the average duration of haemodialysis was 11 ± 26 months.

5.2 Distribution of adverse events

The dissertation reported **33 adverse events** distributed across five categories:

Type of adverse event	Frequency	Percentage
Manpower-related	16	48.5%
Access problem	7	21.2%
Hypotension	6	18.2%
Others	3	9.1%
Bleeding	1	3.0%
Total	33	100%

Manpower-related events represented the largest proportion, followed by access-related problems and hypotension.

These findings suggest that the safety profile of the unit was influenced not only by patient physiology but also by operational and human-resource factors.

6. Root Cause Analysis Findings

The RCA results provide an important insight into the multidimensional nature of dialysis safety.

The identified categories were:

- **Machines**
- **Methods**
- **Manpower**
- **Materials**
- **Management**

The dissertation reported the following distribution:

RCA category	Frequency	Percentage
Machines	5	13.9%
Machines + Manpower	1	2.8%
Methods	2	5.6%
Methods + Manpower	2	5.6%
Methods + Materials	1	2.8%
Manpower	16	44.4%
Manpower + Materials	2	5.6%
Manpower + Management	2	5.6%
Materials	2	5.6%
Management	3	8.3%
Total	36	100%

Manpower was the largest individual category, accounting for 44.4% of RCA observations. Machine-related causes represented 13.9%, while management-related causes represented 8.3%. Importantly, combined categories were also identified, demonstrating interaction between different system components.

The finding that several events had more than one contributing category is important from a quality-management perspective. It indicates that an adverse event should not necessarily be interpreted as the consequence of one isolated action. Instead, it may represent the convergence of several vulnerabilities.

7. Understanding the Root Causes

7.1 Manpower-related factors

Manpower constituted the largest RCA category. In a dialysis unit, staff are responsible for patient assessment, machine preparation, vascular-access management, monitoring, documentation, infection-control procedures and timely response to complications.

Workload, inadequate staffing, variation in experience, training gaps, communication problems and inconsistent adherence to procedures can create conditions in which errors become more likely. The dissertation emphasizes the importance of staff training, teamwork, communication and protocol adherence as components of a safe dialysis environment.

The quality-improvement response should therefore extend beyond individual reminders. It should include competency assessment, structured orientation, continuing education, appropriate staffing, clear role allocation and routine monitoring of compliance.

7.2 Machine-related factors

Dialysis machines represent another important component of the safety system. Equipment malfunction, inadequate maintenance, calibration problems or inappropriate machine operation may contribute to adverse events.

The dissertation identifies machine-related issues as a substantial RCA category and emphasizes preventive maintenance and operational monitoring.

A dialysis-unit quality programme should therefore include preventive-maintenance schedules, documented machine checks, calibration records, prompt reporting of technical problems and clear escalation pathways for equipment failure.

7.3 Method-related factors

Methods include the procedures and workflows used during dialysis. Variation in clinical practice, incomplete adherence to SOPs, inadequate documentation and communication failures can create process vulnerabilities.

Standardized workflows can reduce unnecessary variation. Checklists can be used for patient identification, vascular-access assessment, machine preparation, dialysis initiation, monitoring and termination.

7.4 Material-related factors

Availability and appropriate use of materials can influence safety. Dialysis requires a continuous supply of consumables and vascular-access materials. Interruptions, inappropriate selection or inadequate availability can create delays or procedural risks.

Material management should therefore be integrated into dialysis quality systems through stock monitoring, minimum-stock levels and appropriate storage procedures.

7.5 Management-related factors

Management influences the overall safety environment through staffing decisions, resource allocation, maintenance systems, training policies, reporting mechanisms and quality-monitoring structures.

The dissertation recommends routine adverse-event reporting and periodic RCA meetings, emphasizing that hospital administrators have an important role in strengthening patient-safety strategies.

8. Severity of Adverse Events

The dissertation reported that 47.9% of observations were categorized as having no event, 35.6% as mild and 16.5% as moderate. Thus, most reported adverse events were categorized as mild, with a smaller proportion classified as moderate.

From a quality-improvement perspective, mild events should not be dismissed. Recurrent minor events can act as warning signals of weaknesses in a process. An organization that routinely captures and analyses near misses and low-severity events may identify system vulnerabilities before they result in serious harm.

Therefore, dialysis safety programmes should consider both actual adverse events and near misses as opportunities for organizational learning.

9. Association Between Haemoglobin and Adverse Events

The study also examined the relationship between haemoglobin category and adverse-event occurrence.

The dissertation reported:

Haemoglobin group	Adverse event present	No adverse event	Total
≥8 g/dL	12 (27.3%)	32 (72.7%)	44
<8 g/dL	17 (37.0%)	29 (63.0%)	46

The reported Fisher's exact test was statistically significant ($p=0.035$). The dissertation therefore concluded that haemoglobin category was significantly

associated with adverse-event occurrence.

This finding highlights the importance of integrating patient-level clinical factors into a broader patient-safety strategy. RCA should not be restricted to operational causes. Patient physiology, comorbidities and clinical status may interact with process and organizational factors.

However, the observed association should be interpreted as an association rather than proof of causation.

10. Quality-Improvement Implications

The findings support a shift from reactive management of individual complications toward a structured, continuous quality-improvement model.

A practical dialysis safety cycle can be represented as:

Identify → Report → Analyse → Correct → Monitor → Reassess

10.1 Identify

All clinically relevant adverse events, near misses and process deviations should be recognized.

10.2 Report

A simple, standardized and preferably non-punitive reporting mechanism should be available to all dialysis staff.

10.3 Analyse

Events should be reviewed using RCA tools. Fishbone analysis can identify broad causal domains, while 5 Whys can explore the causal pathway of specific problems.

10.4 Correct

Corrective actions should address system weaknesses rather than merely instructing an individual to “be careful.”

10.5 Monitor

Quality indicators should be tracked over time.

10.6 Reassess

After an intervention, the unit should determine whether the problem has actually decreased.

This approach is consistent with the dissertation's emphasis on continuous monitoring, staff accountability, quality review, standardized procedures and periodic RCA meetings.

11. Recommended Quality-Improvement Interventions for Rural Dialysis Units

Based on the study findings, a practical improvement programme can include the following:

1. Establish a standardized adverse-event reporting system

Every relevant event should be documented using a structured reporting form containing event type, time, circumstances, immediate management, outcome and suspected contributing factors.

2. Conduct periodic RCA meetings

Major events and recurrent minor events should be reviewed by a multidisciplinary team involving nephrologists, nurses, dialysis technicians, hospital administrators and other relevant personnel.

3. Strengthen staff training

Regular competency-based training should address:

- vascular-access care;
- recognition and management of hypotension;
- machine operation;
- emergency procedures;
- infection prevention;
- medication safety;
- documentation; and
- communication and teamwork.

4. Strengthen preventive maintenance

A documented preventive-maintenance programme should include routine machine inspection, calibration, servicing and recording of equipment-related

incidents.

5. Develop and monitor SOPs

Standard operating procedures should be available at the point of care and periodically audited.

6. Strengthen clinical monitoring

Patient-level indicators, including haemoglobin and relevant dialysis parameters, should be regularly reviewed alongside adverse-event data.

7. Develop a non-punitive safety culture

Staff should be encouraged to report errors and near misses without fear of disproportionate blame. RCA should focus on learning and system improvement.

8. Use dashboards for quality indicators

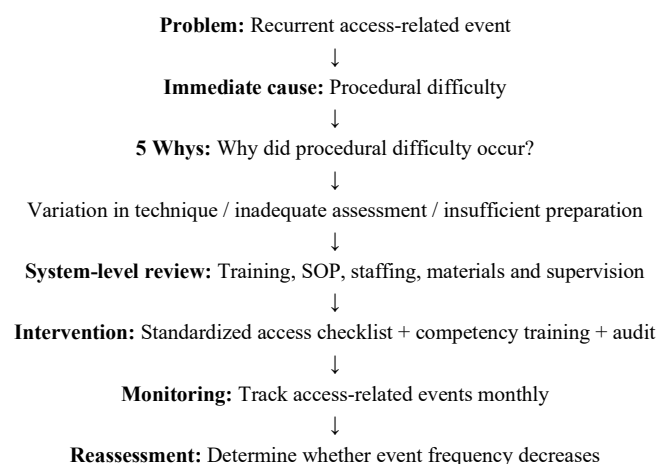
A dialysis-unit safety dashboard can track:

- adverse events per dialysis session;
- hypotension episodes;
- vascular-access complications;
- bleeding events;
- infection indicators;
- machine-related incidents;
- medication-related incidents;
- near misses;
- RCA completion; and
- corrective-action completion.

12. RCA and Continuous Quality Improvement

RCA should not be treated as a one-time investigation. Its value is realized when findings are translated into measurable improvements.

For example:



Such an approach transforms RCA from an investigative exercise into a continuous learning mechanism.

The dissertation similarly conceptualizes RCA as a pathway toward corrective and preventive action and enhanced patient safety.

13. Role of Safety Culture

A sustainable quality-improvement programme requires an organizational culture that considers patient safety a shared responsibility.

Safety culture involves teamwork, communication, openness about errors and organizational commitment to learning. The dissertation notes that a non-punitive environment can encourage reporting and facilitate identification of underlying problems.

In rural hospitals, safety culture can be strengthened without requiring highly sophisticated technology. Regular team meetings, visible SOPs, incident-review meetings, checklist use, feedback and recognition of safety improvements can all support learning.

14. Discussion

The present study demonstrates that adverse events in haemodialysis are multifactorial. Manpower-related events represented the largest reported adverse-event category, while RCA similarly identified manpower as the largest individual root-cause category. Machine, method, material and management factors also contributed, either independently or in combination.

The occurrence of combined RCA categories is particularly relevant. It reinforces the systems approach to patient safety: adverse events may arise when multiple relatively small weaknesses align. This is consistent with the conceptual approach described in the dissertation, which emphasizes interacting human, technical, procedural and organizational factors.

The findings are also consistent with the literature reviewed in the dissertation. Previous studies have identified technical failures, vascular-access problems, medication errors and other complications in haemodialysis. RCA has been used to investigate dialysis-related safety problems, while proactive tools such as Failure Mode and Effects Analysis can identify vulnerabilities before adverse events occur.

The study also reinforces the importance of preventive maintenance and operational monitoring. Although machine-related causes were not the largest individual RCA category, technical factors remained important contributors. This supports a combined approach in which human-resource interventions are accompanied by equipment-management and process-improvement strategies.

The statistically significant association between haemoglobin category and adverse events suggests that patient clinical characteristics should also be incorporated into dialysis safety surveillance. Patient-level risk assessment can complement system-level RCA.

Overall, the findings support the proposition that quality improvement in dialysis should integrate **clinical safety, human factors, equipment management, standardized processes and organizational learning**.

15. Limitations

The study has several limitations that should be considered when interpreting the findings.

First, it was conducted in a single rural tertiary care teaching hospital. Consequently, the findings may not be directly generalizable to other hospitals or dialysis settings.

Second, the sample size was limited to the participants available during the study period.

Third, the dissertation reports that some variables contained missing information and required data cleaning.

Fourth, RCA findings were partly dependent on available documentation. If an event was incompletely documented, some contributing factors may not have been captured.

Finally, the study design does not establish causal relationships between patient characteristics and adverse events.

16. Conclusion

Adverse events in haemodialysis represent the interaction of clinical, technical, human and organizational factors. In the present rural tertiary care teaching hospital, manpower-related events constituted the largest reported category, while RCA identified manpower, machines, methods, materials and management as important contributing domains.

The findings demonstrate the usefulness of structured RCA tools such as Fishbone Diagram and 5 Whys for examining dialysis-related adverse events. Importantly, RCA can help move the focus from individual blame toward identification of modifiable system vulnerabilities.

A sustainable dialysis safety programme should therefore combine standardized procedures, staff training, adequate monitoring, preventive equipment maintenance, clinical surveillance, adverse-event reporting and regular multidisciplinary RCA meetings.

For rural tertiary care hospitals, quality improvement does not necessarily require highly complex interventions. Consistent application of simple, structured safety processes, supported by leadership commitment and a learning-oriented safety culture, can provide a practical foundation for improving haemodialysis safety.

17. Recommendations

Based on the findings of the study, the following measures are recommended:

1. Establish a routine and standardized adverse-event reporting system in the haemodialysis unit.
2. Conduct periodic multidisciplinary RCA meetings.
3. Strengthen staff training and competency assessment.
4. Improve adherence to dialysis-related SOPs.
5. Implement systematic preventive maintenance of dialysis machines.
6. Strengthen infection-control monitoring.
7. Monitor vascular-access complications systematically.
8. Maintain regular clinical monitoring of haemoglobin and other relevant patient indicators.
9. Introduce periodic audits of dialysis safety practices.
10. Encourage reporting of near misses as well as actual adverse events.
11. Develop a dialysis-unit quality dashboard for continuous monitoring.
12. Evaluate corrective actions after implementation rather than considering RCA complete once recommendations are issued.
13. Conduct larger multicentric studies involving rural and urban dialysis facilities.
14. Future research should evaluate the long-term effectiveness of RCA-based interventions and incorporate healthcare-provider perspectives.

These recommendations are consistent with the dissertation's proposed future directions.

REFERENCES

1. Haroon SWP, et al. Risk assessment of failure during transitioning from in-centre to home haemodialysis. *BMC Nephrol.* 2022;23:406.
2. Balson L, Stevenson T, Baharani J. Using root cause analysis as a tool to reduce central venous catheters in haemodialysis patients. *J Vasc Access.* 2022;25(1):239-243.

3. Peerally MF, Dixon-Woods M. Root Cause Analysis Gone Wrong. PSNet. 2018 May 1.
4. Kliger AS, et al. Maintaining safety in the dialysis facility. *Clin J Am Soc Nephrol*. 2014;9(12):2113-2119.
5. Holley JL. A descriptive report of errors and adverse events in chronic haemodialysis units. *Nephrol News Issues*. 2006;20(12):57-63.
6. Rocha RPF, et al. Occurrence of adverse events in public haemodialysis units. *Enferm UERJ*. 2019;27:e36712.
7. Nguyen DB, et al. Haemodialysis-associated infections. *Clin Kidney J*. 2018;11(1):5-13.
8. Walton E, et al. Haemodialysis bleeding events and deaths: an 18-year retrospective analysis. *J Patient Saf*. 2022;18(3):e620-e625.
9. Albreiki S, et al. A systematic literature review of safety culture in haemodialysis settings. *Int J Healthc Manag*. 2023;16(2):130-139.
10. Kumah A, et al. Cause-and-effect (Fishbone) diagram: a tool for root cause analysis. *J Patient Saf Qual Improv*. 2024;12(2):45-51.
11. Reason J. Human error: models and management. *BMJ*. 2000;320(7237):768-770.
12. Leape LL. Error in medicine. *JAMA*. 1994;272(23):1851-1857.
13. Chertow GM, Levin NW, Beck GJ, et al. In-center hemodialysis six times per week versus three times per week. *N Engl J Med*. 2010;363(24):2287-2300.
14. Agarwal R. How can we prevent intradialytic hypotension? *Curr Opin Nephrol Hypertens*. 2012;21(6):593-599.
15. Flythe JE, Kimmel SE, Brunelli SM. Rapid fluid removal during dialysis and cardiovascular morbidity and mortality. *Kidney Int*. 2011;79(2):250-257.
16. Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access. *Am J Kidney Dis*. 2020;75(4 Suppl 2):S1-S164.
17. Daugirdas JT, Blake PG, Ing TS. *Handbook of Dialysis*. 5th ed. Philadelphia: Wolters Kluwer; 2015.
18. Polkinghorne KR, McDonald SP, Atkins RC, Kerr PG. Vascular access and all-cause mortality: a propensity score analysis. *J Am Soc Nephrol*. 2004;15(2):477-486.
19. Mactier R, Hoenich N, Breen C. Renal Association Clinical Practice Guideline on haemodialysis. *Nephron Clin Pract*. 2011;118(Suppl 1):c241-c286.
20. Weinger MB, Pantiskas C, Wiklund ME, Carstensen P. Human factors and patient safety in anesthesia and dialysis care. *Qual Saf Health Care*. 1998;7(Suppl):i47-i52.
21. Kohn LT, Corrigan JM, Donaldson MS. *To Err is Human: Building a Safer Health System*. Washington, DC: National Academy Press; 2000.
22. World Health Organization. *Patient Safety: Making Health Care Safer*. Geneva: WHO; 2017.
23. Percarpio KB, Watts BV, Weeks WB. The effectiveness of root cause analysis: what does the literature tell us? *Jt Comm J Qual Patient Saf*. 2008;34(7):391-398.
24. Vincent C. *Patient Safety*. 2nd ed. Oxford: Wiley-Blackwell; 2010.
25. Institute of Medicine. *Crossing the Quality Chasm: A New Health System for the 21st Century*. Washington, DC: National Academies Press; 2001.
26. Saran R, Robinson B, Abbott KC, et al. US Renal Data System 2020 Annual Data Report: Epidemiology of Kidney Disease in the United States. *Am J Kidney Dis*. 2021;77(4 Suppl 1):A7-A8.
27. Bikbov B, Purcell CA, Levey AS, et al. Global, regional, and national burden of chronic kidney disease. *Lancet*. 2020;395(10225):709-733.
28. Centers for Disease Control and Prevention. Recommendations for preventing transmission of infections among chronic hemodialysis patients. *MMWR Recomm Rep*. 2001;50(RR-5):1-43.
29. Finkelstein FO, Story K, Firaneck C, et al. Health-related quality of life and haemodialysis patients. *Kidney Int Suppl*. 2009;(114):S117-S121.
30. Tschannen D, Aebersold M, McLaughlin E, Bowen J, Fairchild J. Use of virtual simulations for improving patient safety in dialysis settings. *Clin Simul Nurs*. 2012;8(8):e419-e425.