



Care of the chronic dialysis patient in the intensive care unit: a state-of-the-art review

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ABSTRACT

Chronic dialysis patients account for a high proportion of intensive care unit admissions. The prevalent dialysis population is growing worldwide, accompanied by increasing medical complexity and comorbidities. Critical care physicians must be familiar with the unique clinical characteristics of this

patient group. There is relatively little evidence specifically concerning the assessment and treatment of critically unwell individuals on long-term dialysis. This narrative review explores the approach to the management of chronic dialysis patients in the intensive care unit.

Keywords: Dialysis; Intensive care; Renal replacement therapy; Intensive care units

INTRODUCTION

Patients receiving chronic dialysis account for approximately 5% of all intensive care unit (ICU) admissions in the United States and Europe.⁽¹⁾ The prevalent hemodialysis (HD) population has grown by 50% worldwide over the past decade, and further doubling is predicted over the next decade.^(2,3) In many nations, the average age and comorbidity of this patient group has also increased. Chronic dialysis patients present unique medical challenges in the ICU and are associated with poorer outcomes.

Intensive care medicine specialists are providing care for chronic dialysis patients with increasing frequency. However, there are no published guidelines specifically dedicated to the management of chronic dialysis patients with critical illness or those in the ICU. Intensivists may be less familiar with the application of HD in chronic dialysis patients than with the provision of acute renal replacement therapy (RRT).

This narrative review discusses the clinical approach to chronic dialysis patients in the ICU based on the best available evidence. The paper is primarily aimed at critical care physicians who assume the care of chronic dialysis patients in a closed ICU model, in which ICU staff are the primary prescribers of RRT. The term 'chronic dialysis patient' is used throughout to refer to individuals with end-stage renal failure receiving long-term, maintenance, intermittent HD (IHD).

Epidemiology and outcomes

Compared with the general population, chronic dialysis patients have higher rates of ICU admission.⁽⁴⁾ In Australia, for example, 2 - 8% of the prevalent HD population is admitted to an ICU annually, equating to a 36-fold relative risk of ICU admission compared with the nondialysis population.^(5,6) The risk is even greater among indigenous Australians and

in regional and rural centers.^(7,8) Chronic dialysis patients have greater disease severity at ICU admission, longer ICU stays, increased likelihoods of ICU readmission during the same hospitalization, and increased ICU mortality.^(4,9,10) The risk of death in the ICU appears to be at least 50% greater in chronic dialysis patients than in patients without renal impairment.⁽⁹⁻¹¹⁾ The main reasons for ICU referrals in most datasets are sepsis and acute pulmonary edema.^(10,12)

Chronic dialysis patients also have poorer long-term outcomes following ICU admission. Fewer than half of the patients survive longer than 6 months,^(4,13) and the likelihood of hospital readmission after discharge is threefold greater than that of matched controls.⁽¹⁴⁾ Rates of postintensive care syndrome, characterized by poor cognitive and physical function following critical illness in the ICU, are also likely increased, although precise data are lacking. In a cohort study of more than 25,000 consecutive patients treated in American ICUs, HD was significantly associated with the subsequent development of cognitive impairment (hazard ratio [HR] 1.70; 95% confidence interval [95%CI] 1.30 - 2.23).⁽¹⁵⁾ Implicated factors include frailty with a reduced physiologic reserve, malnutrition, and immunosuppression.

Illness severity predictive scoring systems, such as the Acute Physiologic and Chronic Health Evaluation (APACHE) and Sequential Organ Failure Assessment (SOFA), are generally reliable in subjects with end-stage renal failure.^(10,16) However, there is a positive selection bias associated with outcome data, in that high-dependency support is generally offered only to a subset of chronic dialysis patients who are considered healthier.

Intensive care unit clinicians should appreciate the adverse quality-of-life and mortality outcomes of critical illness in chronic dialysis patients. Advance care planning with shared decision-making and clear goal-setting are important. Many chronic dialysis patients are realistic about their prognosis and prefer a conservative rather than an aggressive or invasive approach.⁽¹⁷⁾

Indications for dialysis

Emergency indications for dialysis initiation in acute kidney injury (AKI) are well known. Classic examples include refractory hyperkalemia or volume overload. Chronic dialysis patients who have missed treatment or who develop complications between routine sessions can develop the same emergent indications. Regular outpatient dialysis schedules should be replicated where possible to maintain homeostasis and prevent

complications. Extra treatments might be necessary preemptively when deterioration or invasive interventions are anticipated or when high fluid volumes are administered. The utility of HD following radiocontrast exposure is controversial.

Volume status assessment

Hypervolemia is a constant danger in chronic dialysis patients. Because fluid is frequently administered in large volumes in the ICU, vigilance is needed to prevent serious volume overload. Assessment of volume status can be particularly challenging in the chronic dialysis patient population. Knowledge of the individual's 'target' weight, defined as their euvolemic weight goal during chronic HD, is informative.⁽¹⁸⁾ However, the target weight can be misleading in the context of third-spacing in critical illness. The physical examination should focus on jugular venous pressure, crepitations on lung auscultation, ascites, and leg edema. A physical examination is helpful in the correct clinical context.⁽¹⁹⁻²¹⁾ Although studies of the utility of brain natriuretic peptide and transthoracic echocardiogram have produced mixed results,⁽²²⁻²⁵⁾ chest radiography can accurately detect cardiogenic pulmonary edema regardless of dialysis status.⁽²⁶⁻²⁸⁾ Lung ultrasound, which searches for signs of pulmonary edema, is emerging as a useful tool for setting ultrafiltration targets. Compared with usual care, small randomized trials demonstrated significantly improved long-term blood pressure control and weight reduction in chronic dialysis patients when evaluated with lung ultrasound.^(29,30) The best way to incorporate these strategies into the care of patients in the ICU is unclear.

Fluid resuscitation

No prospective studies have specifically examined fluid resuscitation in chronic dialysis patients. Potential complications of fluid replenishment in people without residual urine output include hypervolemia and hyponatremia. However, chronic dialysis patients may respond differently to fluid therapy than the wider population because of their altered baseline physiology. Retrospective analyses revealed that chronic dialysis patients consistently receive lower fluid volumes in sepsis than their matched peers.⁽³¹⁾ In a secondary analysis of the Protocolized Care for Early Septic Shock (ProCESS) trial, a multicenter randomized controlled trial (RCT) of 1,341 participants with septic shock allocated to protocolized resuscitation versus standard care,⁽³²⁾ outcomes in the chronic dialysis patient subgroup were independent of

the fluid volume received.⁽³³⁾ Similarly, a post hoc analysis of the major RCT by Rivers et al.⁽³⁴⁾ investigating early goal-directed therapy suggested a disproportionate mortality benefit among the small number of included chronic dialysis patients versus other trial participants.⁽³⁵⁾ Several retrospective cohort studies have demonstrated no relationship between a liberal or restrictive fluid resuscitation strategy and rates of endotracheal intubation, hospital length of stay or mortality in septic chronic dialysis patients.⁽³⁶⁾ Although promising, the literature is currently insufficient to recommend early vasopressor use or goal-directed therapy in chronic dialysis patients with shock. Practices must continue to be individualized while further research is awaited.

Renal replacement therapy modalities and vascular access

There is no evidence to support the best way to deliver RRT in the ICU. Prescriptions must be individualized, particularly for chronic dialysis patients. A clear knowledge of the components of the RRT prescription aids the intensivist's understanding of the baseline therapy of chronic dialysis patients and how to complement it during critical illness, such as with adaptation to continuous RRT (CRRT).

Dialysis kinetics

A complete overview of the dialysis kinetics is beyond the scope of this article. However, the fundamental principles of an RRT prescription are applicable to both IHD and CRRT. Although IHD is used by convention as an umbrella term, HD technically defines diffusive solute transfer across a semipermeable dialyzer membrane. Practically, however, IHD also frequently incorporates convective therapies. The most common treatment schedule for IHD is three sessions per week, at 4 hours per session, whereas CRRT is defined as continuous therapy for at least 24 hours.

Compared with a blood flow of 100 - 150 mL/minute for CRRT, outpatient IHD typically utilizes a blood flow rate of at least 300 mL/minute. Dialysate flow rates in intermittent HD approach 500 mL/minute, compared with approximately 30 mL/minute in CRRT.⁽¹²⁾ The dialysate usually runs in a countercurrent direction in both IHD and CRRT. Clearance is relatively more dependent on the blood flow rate in IHD as opposed to the dialysate flow rate in CRRT. Not all dialyzers are compatible with both IHD and CRRT.

Convective solute clearance through hemofiltration or hemodiafiltration enhances middle molecule transport and can be incorporated into both IHD and CRRT. Both require substitution with replacement fluid to account for excess ultrafiltration; the amount and composition of the replacement fluid are variable. Long-term hemodiafiltration may provide a slight mortality benefit over chronic IHD but is uncommonly used worldwide owing to cost constraints. Intermittent hemofiltration is not prescribed because solute clearance is inadequate within short treatment times. In CRRT, the evidence has thus far not demonstrated that hemofiltration or hemodiafiltration is superior to HD alone.

Ultrafiltration is best defined as the convective clearance of plasma solutes and water;⁽³⁷⁾ however, the term 'ultrafiltration' is described inconsistently across nephrology and critical care texts and can cause confusion. Ultrafiltration techniques, in which volume is removed but plasma solute concentrations are largely unchanged because replacement fluid substitution is omitted, are common to both IHD and CRRT. Ultrafiltration is associated with less hemodynamic instability than HD or hemodiafiltration and is often interspersed within dialysis treatments.⁽³⁸⁾ In the context of IHD, ultrafiltration alone is referred to as isolated ultrafiltration, whereas in CRRT, it is known as slow continuous ultrafiltration. In general, the maximal volume removed during IHD and CRRT is approximately 1 L per hour and 150 mL per hour, respectively.

Dialysis dose

The dose refers to the volume of blood purified by the dialysis process. The operating definition varies between IHD and CRRT. In CRRT, the dose is typically represented by the effluent volume, measured in mL/kg/hour. The dose in IHD, also called adequacy, is typically calculated using equations that estimate urea clearance, such as Kt/V (where K = urea clearance, t = treatment time in minutes, and V = urea volume of distribution) or the urea reduction ratio. The dose formulas used in CRRT and IHD are not reciprocal because urea kinetics differ between patient groups and between slow and rapid therapy.^(39,40)

The dialysis dose is a product of the flow rate and therapy time. In patients with AKI, high-quality evidence supports a CRRT dose of 25 - 35 mL/kg/hour.⁽⁴¹⁻⁴³⁾ Intermittent HD with a thrice-weekly Kt/V of 1.2 - 1.4 has also been shown to be adequate in the setting of AKI,^(44,45) however, extra sessions of isolated ultrafiltration may be needed on nondialysis days. The recommended maintenance goal for chronic dialysis patients not in the

ICU is also a Kt/V of 1.2 - 1.4 three times per week or a urea reduction ratio of 60 - 65% per session because of data showing improved mortality.⁽⁴⁶⁾

Intermittent versus continuous renal replacement therapy in the intensive care unit

Although trials have demonstrated no differences in kidney or mortality outcomes between HD modalities when initiated for AKI, their methodology and conclusions have been criticized.^(47,48) Because CRRT is typically preferred in unstable ICU patients, studies are flawed by exclusion or transfer into the CRRT arm of the sickest patients. In some RCTs, approximately 10% of participants allocated to IHD required switching to CRRT because of hemodynamic instability.^(49,50) The advantages of CRRT include superior hemodynamic stability⁽⁵¹⁾ and cerebral perfusion⁽⁵²⁾ and more predictable drug dosing. Compared with systemic heparin anticoagulation, the recent wider use of regional citrate anticoagulation during CRRT has also led to lower rates of bleeding and circuit clotting.⁽⁵³⁾ Given the experience and data thus far, CRRT appears to be the preferred modality in hemodynamically unstable patients, whereas IHD is a suitable step-down option.

Renal replacement therapy is often dictated by pragmatic issues such as center resources. Continuous RRT is increasingly used, but there is significant interregional variation, and IHD remains the prevailing modality in ICUs worldwide.⁽¹²⁾ Continuous RRT accounts for the majority of RRT delivered in ICUs in Australia and New Zealand, whereas IHD is the predominant modality in the United States. Intermittent HD is more cost-effective in most centers. Hybrid techniques, commonly referred to as prolonged intermittent renal replacement therapy or sustained low-efficiency dialysis, are also increasingly encountered and supported by evidence. Sustained low-efficiency dialysis uses IHD technology to deliver therapy more slowly and may represent a valid alternative in many circumstances. Systemic heparin and regional citrate anticoagulation are both suitable methods for anticoagulation during sustained low-efficiency dialysis.⁽⁵⁴⁾

Peritoneal dialysis

In most countries, a minority of patients receive RRT in the form of peritoneal dialysis (PD). In Australia, for example, PD is utilized by 22% of prevalent dialysis patients.⁽⁵⁵⁾ The relative incidence of ICU admission and median ICU length of stay appear to be similar

between PD patients and IHD patients, although the clinical presentations differ. In one study, the most frequent reason for ICU admission among PD patients was for postoperative care.⁽⁵⁶⁾ Urgent-start PD is rarely performed.

In the ICU, many individuals on PD can continue their routine regimen successfully. The nephrology service assists with PD nursing and titration. Clearance and ultrafiltration are dictated by the PD dialysate concentration and the volume and number of exchanges. Peritoneal dialysis is inadequate in some conditions, whereby temporary conversion to HD is unavoidable. Peritoneal dialysis acts slowly in achieving ultrafiltration and biochemical control and relies on a functioning peritoneal membrane. Relative contraindications include recent abdominal surgery, intraabdominal sepsis or other acute processes, respiratory failure, and extreme metabolic derangements. In a Canadian registry study, the likelihood of permanent transfer to HD was 12% if a PD patient was admitted to the ICU.⁽⁵⁷⁾

Renal replacement therapy access

Chronic dialysis patients usually have an upper limb arteriovenous native fistula or synthetic graft. Their pre-existing arteriovenous access (AVA) should be utilized for IHD when feasible. Continuous RRT should not be routinely performed via AVAs because needle dislodgment, infiltration, thrombosis or hematoma may lead to damage or loss of the access. Fatal exsanguination incidents have been reported. In a retrospective study of ICU patients receiving CRRT via AVA for a median of 4 days, the rate of irreparable access loss was 6% and an additional 10% of patients required central venous catheter (CVC) placement due to mechanical AVA complications.⁽⁵⁸⁾ Sustained low-efficiency dialysis could be performed through an AVA, but this option awaits further study. The use of an AVA requires a trained dialysis nurse with vigilant monitoring of the site throughout treatment.

If a CVC must be placed acutely for HD in subjects with a functioning AVA, such as for CRRT or when no trained personnel are available for cannulation, a femoral nontunneled line may be reasonable. This prevents traumatic injury to the jugular and subclavian veins, maintaining patency for future purposes. In most cases, the shorter dwell time allowed by femoral catheters should be sufficient to stabilize the patient to a point where reversion to IHD via their existing AVA is acceptable. If an AVA fails, a tunneled HD catheter is inevitably needed and is preferred upfront to circumvent unnecessary

procedures. Tunneled CVCs are placed by critical care physicians in some centers. The right internal jugular vein is the first-line cannulation approach for tunneled lines in most instances.

General vascular access

Securing reliable intravenous access can be problematic in chronic dialysis patients with an extensive history of vascular interventions. The impact on current or future AVAs should be considered. Central venous access is typically obtained via the jugular or femoral vein. Subclavian CVCs are avoided ipsilateral to a current or future AVA. Tunneled small-bore CVCs are being explored as an alternative to peripherally inserted central catheters. Peripherally inserted central catheter placement is associated with central vein stenosis and upper limb deep vein thrombosis and is an independent predictor of future adverse AVA outcomes.^(59,60)

Phlebotomy, peripheral intravenous cannulation, or the placement of an intra-arterial cannula near a current or anticipated AVA is discouraged. Cannulation attempts are preferred distal to the site, such as in veins on the dorsum of the hand, rather than proximal. Anecdotally, preserving vessel integrity appears to increase AVA maturation and longevity. Arteriovenous access should also be protected from accidental compression in ventilated patients and from the application of armbands or blood pressure cuffs over the site.

Direct cannulation of an AVA is not contraindicated in emergency conditions where there is no alternative. Indeed, rapidly accessing an AVA may be prudent since stasis in the setting of prolonged hypotension is an independent risk factor for AVA thrombosis.⁽⁶¹⁾ The steps of AVA cannulation are similar to those of peripheral intravenous cannulation: an upper arm tourniquet is tightened to distend the vessel, after which the cannula is inserted into the outflow venous limb of the AVA in a downstream direction. The findings of blood gas samples from the AVA are almost indistinguishable from those of radial arterial blood gas samples.⁽⁶²⁾

Intradialytic emergencies

Life-threatening intradialytic complications, either in the ICU or the outpatient dialysis unit, are rarer among chronic dialysis patients than among those acutely commencing HD. Emergencies may be related specifically to dialysis or represent the exacerbation of an underlying or unrelated condition. Because evidence-based data are scarce, interventions in the ICU should be made on a

case-by-case basis, and core resuscitation principles should be prioritized.

Hypotension

Intradialytic hypotension is typically mild and is explained by volume and osmotic changes. Judicious crystalloid fluid boluses and reduced ultrafiltration restore blood pressure in most instances. However, dialysis-related hypotension can sometimes be profound; differential diagnoses for these severe cases include sepsis, decompensated heart failure, and myocardial infarction. Temporary cessation of HD is often necessary while the patient is stabilized. Persistent hypotension necessitates intravenous vasopressor support to facilitate further treatment. Vasopressor choices are analogous to those of the general population. Intravenous calcium may be a helpful adjunct. Because most chronic dialysis patients are conditioned to hypertension at baseline, the preferred acute blood pressure goals are uncertain.

Anaphylaxis

The incidence of anaphylaxis is less than 4 cases per 100,000 RRT treatments.⁽⁶³⁾ Adverse allergic reactions can occur after exposure to any part of the HD apparatus or to medications administered during treatment. The therapeutic approach to intradialytic anaphylaxis mirrors other settings. Renal replacement therapy should be stopped, and contaminated fluid or blood should be discarded. Further dialysis is absolutely contraindicated until the patient is stabilized, potential sources are removed, and fresh equipment is available.

Neurologic disturbances

Intradialytic encephalopathy manifests on a spectrum ranging from mild confusion to seizures or coma. Uremic encephalopathy and dialysis disequilibrium syndrome are the main concerns. Uremic encephalopathy is neurologic dysfunction caused by the toxic effects of uremia, whereas disequilibrium syndrome is thought to be related to precipitous urea clearance and osmotic shifts that induce cerebral edema. The dialysis prescription should be slowed or paused in cases of intradialytic encephalopathy. Continuous RRT is probably better tolerated than IHD for this purpose. Empiric hypertonic saline or mannitol may be indicated in unstable patients to reverse cerebral edema.

Cardiac arrest

The incidence of cardiac arrest is approximately 1 event per 20,000 outpatient IHD treatments.⁽⁶⁴⁾ The relative

risk of intradialytic cardiac arrest is likely greater in the ICU because of predisposing factors. Most cases involve nonshockable rhythms. The etiology of dialysis-related cardiac arrest is thought to primarily reflect hypotension and the arrhythmogenic state. Advanced life support should be provided in accordance with professional guidelines. However, some nuances specific to the dialysis setting may be beneficial. Empiric pharmacologic treatment for acidemia and hyperkalemia is usually appropriate. Other interventions specific to intradialytic cardiac arrest may also include immediate cessation of dialysis, disconnection of unnecessary tubing, and a fluid bolus.

Infections in chronic dialysis patients

Long-term dialysis results in increased susceptibility to infection.⁽⁶⁵⁾ The likelihood of infection with multiresistant organisms is particularly high.⁽⁶⁶⁾ Sepsis is more common in chronic dialysis patients than in the general population and is associated with a significantly greater relative risk of

death.^(9,67) The most frequent sources of sepsis associated with ICU admission in chronic dialysis patients are pneumonia and cellulitis,⁽⁹⁾ whereas the leading causes of infection-related death are vascular access infection and respiratory tract infection.⁽³⁷⁾ Hemodialysis vascular access should be examined as a potential source in patients with bacteremia. Antibiotic agents must be dosed with reference to intrinsic renal elimination and drug dialysability. Intravenous antibiotics administered with intermittent HD are a convenient option in appropriate circumstances.

Daily intensive care unit checklist

Daily rounding in the ICU should incorporate a range of evidence-based preventative interventions, often using standardized checklists. The most recognized checklist is FAST HUG (feeding, analgesia, sedation, thromboprophylaxis, head up, ulcer prophylaxis, glucose).⁽⁶⁸⁾ The best practices for chronic dialysis patients are reviewed in table 1.

Table 1 - Routine supportive care for chronic dialysis patients in the intensive care unit

Feeds and fluids	<ul style="list-style-type: none"> Malnutrition is highly prevalent Enteral and parenteral nutrition are well-tolerated but can result in fluid overload necessitating additional dialysis. Diuretic responsiveness is poor. In the community, dialysis patients usually require a daily fluid restriction to 1L No robust evidence supports a 'renal' dietary formula (i.e., concentrated, electrolyte-restricted) over standard nutritional supplementation Nonwater body mass is lost rapidly through deconditioning. The target weight must be adjusted to avoid hypervolemia
Analgesia and sedation	<ul style="list-style-type: none"> Renal insufficiency affects the pharmacokinetics and pharmacodynamics of some anesthetic and analgesic agents. Drugs that are not renally cleared are preferable Propofol is not markedly altered by end-stage renal failure and can be titrated to effect⁽⁶⁹⁾ There is interindividual variability in the response to opiates; short-acting agents such as fentanyl are less affected by renal impairment than long-acting alternatives such as morphine⁽⁷⁰⁻⁷¹⁾ Midazolam is minimally affected by kidney function in bolus doses but accumulates with longer infusions
Thromboprophylaxis	<ul style="list-style-type: none"> There is an increased incidence of venous thromboembolism Chemical venous thromboembolism prophylaxis may be associated with reduced mortality⁽⁷²⁾ At our hospital we frequently give subcutaneous unfractionated heparin 5,000U twice daily or enoxaparin 20mg daily
Ulcer prophylaxis	<ul style="list-style-type: none"> Renal replacement therapy is a risk factor for stress ulcer bleeding Routine pharmacologic ulcer prophylaxis is of uncertain benefit
Bowel management	<ul style="list-style-type: none"> Polyethylene glycol laxatives and sodium phosphate enemas may induce electrolyte and acid-base disturbances and volume overload
Indwelling catheters	<ul style="list-style-type: none"> Observational studies show higher infection rates for temporary jugular and femoral hemodialysis central venous catheters beyond approximately 21 and 7 days, respectively.⁽⁷³⁾ However, the optimal time for preemptive central venous catheter exchange is unknown Tunneled peritoneal dialysis catheters may be complicated by exit-site infection or peritonitis. Peritoneal dialysis catheter removal is performed by the interventionalist or surgeon Peripheral cannulas sited near an arteriovenous access should be relocated when appropriate

Perioperative care

The perioperative management of chronic dialysis patients can be challenging. This cohort has higher rates of surgery and is more likely to require postoperative ICU admission than the matched population.^(74,75) Postoperative morbidity and mortality are also greater, particularly after unplanned surgery.^(76,77) Plans should be made for RRT before and after surgery, as adequate perioperative dialysis is associated with fewer complications, such as infection, wound breakdown, bleeding and pulmonary edema.^(37,78,79) Transfusion requirements may be raised due to impaired erythropoiesis. Aggressive erythropoietin dosing for acute anemia is ineffective in the short term. Pharmacologic reversal agents for uremic bleeding include tranexamic acid and desmopressin. Renal replacement therapy anticoagulation may need to be minimized. Intravenous fluids must be used cautiously to avoid hypervolemia. Compared with balanced crystalloid solutions, 0.9% sodium chloride slightly increases the incidence of hyperchloremic acidosis but not hyperkalemia.^(80,81)

Kidney transplantation

Many chronic dialysis patients are candidates for future kidney transplantation. Pretransplant status may affect therapy decisions in the ICU. For example, blood transfusion leads to antigen sensitization, negatively impacts graft outcomes, and should be avoided where possible.⁽⁸²⁾ Leuko-depleted blood products are preferred.^(82,83) Temporary coverage with an oral immunosuppressive agent, such as cyclosporin, reduces antibody formation and is still recommended by some centers on the basis of very low-quality evidence.^(84,85) Consultation with nephrology is crucial. Femoral CVCs or arterial lines are discouraged to preserve the iliac vessels for future transplant surgery or to avoid anastomotic or embolic injury to a current graft.

Directions for future research

Resuscitation strategies for chronic dialysis patients are debated. There is no convincing evidence for a specific approach in this patient group. The best implementation of fluids and vasopressors may be different in the context of unique baseline physiology. The relevance of endothelial glycocalyx abnormalities in patients with sepsis and chronic kidney disease is also attracting interest.⁽⁸⁶⁾ Both the measurement of glycocalyx degradation to guide fluid resuscitation and the use of the glycocalyx as a therapeutic target are being investigated.⁽⁸⁷⁾

Extracorporeal blood purification is being investigated for its therapeutic role in septic shock. Hemoperfusion or high-dose, high-flux hemofiltration can be utilized for cytokine and endotoxin removal. The fact that the therapy itself activates inflammatory mediators is a limitation. Other problems include hematologic and metabolic derangements. Extracorporeal

purification is not yet supported by rigorous data, and further research is warranted. Compared with other groups, there may be greater utility in septic chronic dialysis patients with preexisting vascular access and long-term exposure to extracorporeal therapy.

Health care resource utilization should be a focus of future studies. There is an overreliance on ICUs to accommodate chronic dialysis patients. Intensive care unit admissions are frequently brief and focus on expediting RRT. Better utilization of acute medical or coronary care units may be possible in cases of lower complexity. Modifications to ward resourcing and staffing models, particularly to increase the capability for after-hours dialysis, may reduce the need for ICU referrals. The contest between open and closed high-dependency models remains controversial,⁽⁸⁸⁾ likely depends on regional factors, and should be further evaluated.

CONCLUSION

Caring for chronic dialysis patients in the intensive care unit can be challenging. The heterogeneity of this patient cohort, including their altered baseline physiology, and a lack of supporting evidence, highlights the importance of individualized care. The appreciation of patients' baseline intermittent hemodialysis regimens can inform tailored provision of renal replacement therapy in the intensive care unit. A structured approach to routine intensive care unit care, such as deep vein thrombosis prophylaxis and antibiotic stewardship, is also important. Resuscitation strategies and improving the utilization of hospital resources by chronic dialysis patients are priorities for future research.

Publisher's note

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REFERENCES

1. Thompson S, Pannu N. Dialysis patients and critical illness. *Am J Kidney Dis.* 2012;59(1):145-51.

2. Himmelfarb J, Vanholder R, Mehrotra R, Tonelli M. The current and future landscape of dialysis. *Nsat Rev Nephrol.* 2020;16(10):573-85.
3. Liyanage T, Ninomiya T, Jha V, Neal B, Patrice HM, Okpechi I, et al. Worldwide access to treatment for end-stage kidney disease: a systematic review. *Lancet.* 2015;385(9981):1975-82.
4. Chan M, Ostermann M. Outcomes of chronic hemodialysis patients in the intensive care unit. *Crit Care Res Pract.* 2013;2013:715807.
5. Uchino S, Morimatsu H, Bellomo R, Silvester W, Cole L. End-stage renal failure in patients requiring renal replacement therapy in the intensive care unit: incidence, clinical features, and outcome. *Blood Purif.* 2003;21(2):170-5.
6. Keuskamp D, Davies C, Clayton PA, Pilcher DV, Chavan S, Secombe PJ, et al. Intensive care admissions for dialysis and transplant patients 2018-2020: an Australian data linkage study. Australian and New Zealand Society of Nephrology Annual Scientific Meeting; 2022 July 19; Sydney. Australian and New Zealand Society of Nephrology [cited 2024 March 7]. Available from: <https://anzsnsm.com/15546>
7. Dunlop WA, Secombe PJ, Agostino JW, van Haren FM. Characteristics and outcomes of Aboriginal and Torres Strait Islander patients with dialysis-dependent kidney disease in Australian intensive care units. *Intern Med J.* 2022;52(3):458-67.
8. Secombe P, Chiang PY, Pawar B; Alice Springs Hospital Renal-ICU Research Group. Resource use and outcomes in patients with dialysis-dependent chronic kidney disease admitted to intensive care. *Intern Med J.* 2019;49(10):1252-61.
9. Strijack B, Mojica J, Sood M, Komenda P, Bueti J, Reslerova M, et al. Outcomes of chronic dialysis patients admitted to the intensive care unit. *J Am Soc Nephrol.* 2009;20(11):2441-7.
10. Arulkumaran N, Annear NM, Singer M. Patients with end-stage renal disease admitted to the intensive care unit: systematic review. *Br J Anaesth.* 2013;110(1):13-20.
11. Clermont G, Acker CG, Angus DC, Sirio CA, Pinsky MR, Johnson JP. Renal failure in the ICU: comparison of the impact of acute renal failure and end-stage renal disease on ICU outcomes. *Kidney Int.* 2002;62(3):986-96.
12. Szamosfalvi B, Yee J. Considerations in the critically ill ESRD patient. *Adv Chronic Kidney Dis.* 2013;20(1):102-9.
13. Manhes G, Heng AE, Aublet-Cuvelier B, Gazuy N, Deteix P, Souweine B. Clinical features and outcome of chronic dialysis patients admitted to an intensive care unit. *Nephrol Dial Transplant.* 2005;20(6):1127-33.
14. Sood MM, Roberts D, Komenda P, Bueti J, Reslerova M, Mojica J, et al. End-stage renal disease status and critical illness in the elderly. *Clin J Am Soc Nephrol.* 2011;6(3):613-9.
15. Guerra C, Linde-Zwirble WT, Wunsch H. Risk factors for dementia after critical illness in elderly Medicare beneficiaries. *Crit Care.* 2012;16(6):R233.
16. Juneja D, Prabhu MV, Gopal PB, Mohan S, Sridhar G, Nayak KS. Outcome of patients with end stage renal disease admitted to an intensive care unit in India. *Ren Fail.* 2010;32(1):69-73.
17. Moorman D, Mallick R, Rhodes E, Bieber B, Nesrallah G, Davis J, et al. Facility variation and predictors of do not resuscitate orders of hemodialysis patients in Canada: DOPPS. *Can J Kidney Health Dis.* 2019;6:2054358119879777.
18. Sinha AD, Agarwal R. Can chronic volume overload be recognized and prevented in hemodialysis patients? The pitfalls of the clinical examination in assessing volume status. *Semin Dial.* 2009;22(5):480-2.
19. Garfinkle MA, Barton J. Pedal edema and jugular venous pressure for volume overload in peritoneal dialysis patients. *Can J Kidney Health Dis.* 2016;3:1.
20. Bassat OK, Raz MA, Grupper A. Volume status assessed by physical examination correlates with lung ultrasound findings in patients with CKD. *J Am Soc Nephrol.* 2023;34(11S):160.
21. Annamalai I, Balasubramaniam S, Fernando ME, Srinivasaprasad ND, Sureen S, Thirumalavalan K, et al. Volume assessment in hemodialysis: a comparison of present methods in clinical practice with sonographic lung comets. *Indian J Nephrol.* 2019;29(2):102-10.
22. Zhu F, Rosales L, Kotanko P. Techniques for assessing fluids status in patients with kidney disease. *Curr Opin Nephrol Hypertens.* 2016;25(6):473-9.
23. Agarwal R. B-type natriuretic peptide is not a volume marker among patients on hemodialysis. *Nephrol Dial Transplant.* 2013;28(12):3082-9.
24. Anwaruddin S, Lloyd-Jones DM, Baggish A, Chen A, Krauser D, Tung R, et al. Renal function, congestive heart failure, and amino-terminal pro-brain natriuretic peptide measurement: results from the ProBNP Investigation of Dyspnea in the Emergency Department (PRIDE) Study. *J Am Coll Cardiol.* 2006;47(1):91-7.
25. Agarwal R, Bouldin JM, Light RP, Garg A. Inferior vena cava diameter and left atrial diameter measure volume but not dry weight. *Clin J Am Soc Nephrol.* 2011;6(5):1066-72.
26. Frank Peacock W, Soto KM. Current technique of fluid status assessment. *Congest Heart Fail.* 2010;16(Suppl 1):S45-51.
27. Wang CS, FitzGerald JM, Schulzer M, Mak E, Ayas NT. Does this dyspneic patient in the emergency department have congestive heart failure? *JAMA.* 2005;294(15):1944-56.
28. Widiastuti, Dewi RT, Murti B, Ruth E, Maryetty IP, Hermansah M, et al. The correlation between disease stage and pulmonary edema assessed with chest X-ray in chronic kidney disease patients. *Imaging Med.* 2021;13(1):1-6.
29. Loutradis C, Sarafidis PA, Ekart R, Tsouchnikas I, Papadopoulos C, Kamperidis V, et al. Ambulatory blood pressure changes with lung ultrasound-guided dry-weight reduction in hypertensive hemodialysis patients: 12-month results of a randomized controlled trial. *J Hypertens.* 2021;39(7):1444-52.
30. Loutradis C, Sarafidis PA, Ekart R, Papadopoulos C, Sachpekidis V, Alexandrou ME, et al. The effect of dry-weight reduction guided by lung ultrasound on ambulatory blood pressure in hemodialysis patients: a randomized controlled trial. *Kidney Int.* 2019;95(6):1505-13.
31. Haley M, Foroutan NK, Gronquist JM, Reddy R, Wusirika R, Khan A. Fluid resuscitation and sepsis management in patients with chronic kidney disease or end-stage renal disease: scoping review. *Am J Crit Care.* 2024;33(1):45-53.
32. ProCESS Investigators; Yealy DM, Kellum JA, Huang DT, Barnato AE, Weissfeld LA, Pike F, et al. A randomized trial of protocol-based care for early septic shock. *N Engl J Med.* 2014;370(18):1683-93.
33. Huebinger RM, Walia S, Yealy DM, Kellum JA, Huang DT, Wang HE. Outcomes of end-stage renal disease patients in the PROCESS trial. *J Am Coll Emerg Physicians Open.* 2021;2(1):e12358.
34. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E, Tomlanovich M; Early Goal-Directed Therapy Collaborative Group. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *N Engl J Med.* 2001;345(19):1368-77.
35. Arulkumaran N, Montero RM, Singer M. Management of the dialysis patient in general intensive care. *Br J Anaesth.* 2012;108(2):183-92.
36. Khan RA, Khan NA, Bauer SR, Li M, Duggal A, Wang X, Reddy AJ. Association between volume of fluid resuscitation and intubation in high-risk patients with sepsis, heart failure, end-stage renal disease, and cirrhosis. *Chest.* 2020;157(2):286-92.
37. Levy J, Brown E, Lawrence A. *Oxford handbook of dialysis.* 4th ed. Oxford, UK: Oxford University Press; 2016.
38. Keijman JM, van der Sande FM, Kooman JP, Leunissen KM. Thermal energy balance and body temperature: comparison between isolated ultrafiltration and haemodialysis at different dialysate temperatures. *Nephrol Dial Transplant.* 1999;14(9):2196-200.
39. Clark WR, Leblanc M, Ricci Z, Ronco C. Quantification and dosing of renal replacement therapy in acute kidney injury: a reappraisal. *Blood Purif.* 2017;44(2):140-55.
40. Daugirdas JT, Blake PG, Ing TS. *Handbook of dialysis.* 5th ed. Philadelphia, PA: Lippincott Williams and Wilkins; 2015.

41. Vaara ST, Serpa-Neto A, Bellomo R, Adhikari NKJ, Dreyfuss D, Gallagher M, Gaudry S, Hoste E, Joannidis M, Pettilä V, Wang AY, Kashani K, Wald R, Bagshaw SM, Ostermann M; Standard vs. Accelerated initiation of Renal Replacement Therapy in Acute Kidney Injury (STARTR-AKI) Investigators. Regional practice variation and outcomes in the standard versus accelerated initiation of renal replacement therapy in acute kidney injury (STARTR-AKI) trial: a post hoc secondary analysis. *Crit Care Explor.* 2024;6(2):e1053.
42. RENAL Replacement Therapy Study Investigators; Bellomo R, Cass A, Cole L, Finfer S, Gallagher M, Lo S, et al. Intensity of continuous renal-replacement therapy in critically ill patients. *N Engl J Med.* 2009;361(17):1627-38.
43. Palevsky PM, O'Connor TZ, Chertow GM, Crowley ST, Zhang JH, Kellum JA; US Department of Veterans Affairs/National Institutes of Health Acute Renal Failure Trial Network. Intensity of renal replacement therapy in acute kidney injury: perspective from within the Acute Renal Failure Trial Network Study. *Crit Care.* 2009;13(4):310.
44. Eknoyan G, Beck GJ, Cheung AK, Daugirdas JT, Greene T, Kusek JW, Allon M, Bailey J, Delmez JA, Depner TA, Dwyer JT, Levey AS, Levin NW, Milford E, Ornt DB, Rocco MV, Schulman G, Schwab SJ, Teehan BP, Toto R; Hemodialysis (HEMO) Study Group. Effect of dialysis dose and membrane flux in maintenance hemodialysis. *N Engl J Med.* 2002;347(25):2010-9.
45. Kidney Disease: Improving Global Outcomes (KDIGO). KDIGO Clinical Practice Guideline for Acute Kidney Injury. *Kidney Int.* 2012;2(Suppl 1):1-138.
46. Owen WF Jr, Lew NL, Liu Y, Lowrie EG, Lazarus JM. The urea reduction ratio and serum albumin concentration as predictors of mortality in patients undergoing hemodialysis. *N Engl J Med.* 1993;329(14):1001-6.
47. Ravidranath K, Adams J, Macleod AM, Muirhead N. Intermittent versus continuous renal replacement therapy for acute renal failure in adults. *Cochrane Database Syst Rev.* 2007;18(3):CD003773.
48. Nash DM, Przech S, Wald R, O'Reilly D. Systematic review and meta-analysis of renal replacement therapy modalities for acute kidney injury in the intensive care unit. *J Crit Care.* 2017;41:138-44.
49. Augustine JJ, Sandy D, Seifert TH, Paganini EP. A randomized controlled trial comparing intermittent with continuous dialysis in patients with ARF. *Am J Kidney Dis.* 2004;44(6):1000-7.
50. Davenport A, Will EJ, Davison AM. Continuous vs. intermittent forms of haemofiltration and/or dialysis in the management of acute renal failure in patients with defective cerebral autoregulation at risk of cerebral oedema. *Contrib Nephrol.* 1991;93:225-33.
51. Schefold JC, von Haehling S, Pischowski R, Bender T, Berkmann C, Briegel S, et al. The effect of continuous versus intermittent renal replacement therapy on the outcome of critically ill patients with acute renal failure (CONVINT): a prospective randomized controlled trial. *Crit Care.* 2014;18(1):R11.
52. Vinsonneau C, Camus C, Combes A, Costa de Beauregard MA, Klouche K, Boulain T, et al.; Hemodiafe Study Group. Continuous venovenous haemodiafiltration versus intermittent haemodialysis for acute renal failure in patients with multiple-organ dysfunction syndrome: a multicentre randomised trial. *Lancet.* 2006 Jul;368(9533):379-85.
53. Zarbock A, Küllmar M, Kindgen-Milles D, Wempe C, Gerss J, Brandenburger T, Dimski T, Tyczynski B, Jahn M, Mülling N, Mehrländer M, Rosenberger P, Marx G, Simon TP, Jaschinski U, Deetjen P, Putensen C, Schewe JC, Kluge S, Jarczack D, Slowinski T, Bodenstern M, Meybohm P, Wirtz S, Moerer O, Kortgen A, Simon P, Bagshaw SM, Kellum JA, Meersch M; RICH Investigators and the Sepnet Trial Group. Effect of regional citrate anticoagulation vs systemic heparin anticoagulation during continuous kidney replacement therapy on dialysis filter life span and mortality among critically ill patients with acute kidney injury: a randomized clinical trial. *JAMA.* 2020;324(16):1629-39.
54. Wen M, Küchle C, Steubl D, Satanovskij R, Heemann U, Suttman Y, et al. A novel citrate-based protocol versus heparin anticoagulation for sustained low-efficiency dialysis in the ICU: safety, efficacy, and cost. *BMC Nephrol.* 2018;19(1):79.
55. Gray NA, Grace BS, McDonald SP. Peritoneal dialysis in rural Australia. *BMC Nephrol.* 2013 Dec;14(1):278.
56. Bakkaloğlu SA, Özdemir Atikel Y, Schmitt CP, Lévai E, Adalat S, Goodman N, et al. Comparative analysis of hospitalizations among patients treated with hemodialysis and peritoneal dialysis in European pediatric nephrology centers: results from a prospective EPDWG/ESPN Dialysis Working Group study. *Clin Kidney J.* 2023;17(1):sfad291.
57. Khan A, Rigatto C, Verrelli M, Komenda P, Mojica J, Roberts D, et al. High rates of mortality and technique failure in peritoneal dialysis patients after critical illness. *Perit Dial Int.* 2012;32(1):29-36.
58. Al Rifai A, Sukul N, Wonnacott R, Heung M. Safety of arteriovenous fistulae and grafts for continuous renal replacement therapy: the Michigan experience. *Hemodial Int.* 2018;22(1):50-5.
59. McGill RL, Ruthazer R, Meyer KB, Miskulin DC, Weiner DE. Peripherally inserted central catheters and hemodialysis outcomes. *Clin J Am Soc Nephrol.* 2016;11(8):1434-40.
60. El Ters M, Schears GJ, Taler SJ, Williams AW, Albright RC, Jensen BM, et al. Association between prior peripherally inserted central catheters and lack of functioning arteriovenous fistulas: a case-control study in hemodialysis patients. *Am J Kidney Dis.* 2012;60(4):601-8.
61. Chang TI, Paik J, Greene T, Desai M, Bech F, Cheung AK, et al. Intradialytic hypotension and vascular access thrombosis. *J Am Soc Nephrol.* 2011;22(8):1526-33.
62. Menezes MD, Caeiro F, Fernandes S, Nolasco F. Validation of blood gas analysis in arteriovenous fistula for hemodialysis. *Semin Dial.* 2022;35(4):343-7.
63. Daugirdas JT, Ing TS. First-use reactions during hemodialysis: a definition of subtypes. *Kidney Int Suppl.* 1988;24:S37-43.
64. Tanaka T, Nomura Y, Hirama C, Takamatsu Y, Wakatake H, Suzuki T, et al. Cardiac arrest during haemodialysis: a survey of five Japanese hospitals. *Acute Med Surg.* 2020;7(1):476.
65. Ishigami J, Matsushita K. Clinical epidemiology of infectious disease among patients with chronic kidney disease. *Clin Exp Nephrol.* 2019;23(4):437-47.
66. Calfee DP. Multidrug-resistant organisms within the dialysis population: a potentially preventable perfect storm. *Am J Kidney Dis.* 2015;65(1):3-5.
67. Bou Chebl R, Tamim H, Abou Dagher G, Sadat M, Ghamdi G, Itani A, et al. Sepsis in end-stage renal disease patients: are they at an increased risk of mortality? *Ann Med.* 2021;53(1):1737-43.
68. Vincent JL. Give your patient a fast hug (at least) once a day. *Crit Care Med.* 2005;33(6):1225-9.
69. Ickx B, Cockshott ID, Barvais L, Byttebier G, De Pauw L, Vandesteene A, et al. Propofol infusion for induction and maintenance of anaesthesia in patients with end-stage renal disease. *Br J Anaesth.* 1998;81(6):854-60.
70. Hoke JF, Shlugman D, Dershwitz M, Michalowski P, Malthouse-Dufore S, Connors PM, et al. Pharmacokinetics and pharmacodynamics of remifentanyl in persons with renal failure compared with healthy volunteers. *Anesthesiology.* 1997;87(3):533-41.
71. Dean M. Opioids in renal failure and dialysis patients. *J Pain Symptom Manage.* 2004;28(5):497-504.
72. Godhwani A, Tran A, Rybka D. What is the optimal pharmacologic VTE prophylaxis in the hospitalised dialysis patient? *Evid Based Pract.* 2021;24(7):33-4.
73. Oliver MJ, Callery SM, Thorpe KE, Schwab SJ, Churchill DN. Risk of bacteremia from temporary hemodialysis catheters by site of insertion and duration of use: a prospective study. *Kidney Int.* 2000;58(6):2543-5.
74. Palamuthasingam D, Hawley CM, Pascoe EM, Johnson DW, Palamuthasingam P, Boudville N, et al. Postoperative outcomes after gastrointestinal surgery in patients receiving chronic kidney replacement therapy: a population-based cohort study. *Ann Surg.* 2024;279(3):462-70.
75. Palamuthasingam D, Hawley CM, Pascoe EM, Johnson DW, Sivalingam P, McDonald S, et al. Trends in rates of surgery and postoperative mortality among patients receiving chronic kidney replacement therapy: a population-based cohort study. *Ann Surg.* 2022;276(6):1002-10.

76. Palamuthusingam D, Nadarajah A, Johnson DW, Pascoe EM, Hawley CM, Fahim M. Morbidity after elective surgery in patients on chronic dialysis: a systematic review and meta-analysis. *BMC Nephrol*. 2021;22(1):97.
77. Palamuthusingam D, Johnson DW, Hawley CM, Pascoe E, Sivalingam P, Fahim M. Perioperative outcomes and risk assessment in dialysis patients: current knowledge and future directions. *Intern Med J*. 2019;49(6):702-10.
78. Fielding-Singh V, Vanneman MW, Grogan T, Neelankavil JP, Winkelmayer WC, Chang TI, et al. Association between preoperative haemodialysis timing and postoperative mortality in patients with end-stage kidney disease. *JAMA*. 2022;328(18):1837-48.
79. Okada H, Tsukamoto I, Sugahara S, Nakamoto H, Oohama K, Yamashita Y, et al. Does intensive perioperative dialysis improve the results of coronary artery bypass grafting in haemodialysed patients? *Nephrol Dial Transplant*. 1999;14(3):771-5.
80. O'Malley CM, Frumento RJ, Hardy MA, Benvenisty AI, Brentjens TE, Mercer JS, et al. A randomized, double-blind comparison of lactated Ringer's solution and 0.9% NaCl during renal transplantation. *Anesth Analg*. 2005;100(5):1518-24.
81. Collins MG, Fahim MA, Pascoe EM, Hawley CM, Johnson DW, Varghese J, et al.; BEST-Fluids Investigators; Australasian Kidney Trials Network. Balanced crystalloid solution versus saline in deceased donor kidney transplantation (BEST-Fluids): a pragmatic, double-blind, randomised, controlled trial. *Lancet*. 2023;402(10396):105-17.
82. Chapter 1: Diagnosis and evaluation of anemia in CKD. *Kidney Int Suppl* (2011). 2012;2(4):288-91.
83. Cincinnati Children's. Evidence-Based Guideline 50. Blood Product Administration in Children and Young Adults Likely to Need a Solid Organ Transplant [Internet]. Cincinnati: Cincinnati Children's Hospital Medical Centre; 2020 [updated 2020; cited 2024 July 3]. Available from: <https://www.cincinnatichildrens.org/research/divisions/janderson-center/evidence-based-care/recommendations>
84. Raftery MJ, Lang CJ, O'Shea JM, Varghese Z, Sweny P, Fernando ON, et al. Controlled trial of azathioprine and cyclosporin to prevent anti-HLA antibodies due to third-party transfusion. *Nephrol Dial Transplant*. 1988;3(5):671-6.
85. Scornik JC, Meier-Kriesche HU. Blood transfusions in organ transplant patients: mechanisms of sensitization and implications for prevention. *Am J Transplant*. 2011;11(9):1785-91.
86. Campbell VK, Gately RP, Krishnasamy R, Burg D, Robertson GR, Gray NA. Midline and chronic kidney disease-associated multisystem organ dysfunctions. *Nephrol Dial Transplant*. 2021;36(9):1577-84.
87. Uchimido R, Schmidt EP, Shapiro NI. The glycocalyx: a novel diagnostic and therapeutic target in sepsis. *Crit Care*. 2019;23(1):16.
88. Guidet B, Kentish-Barnes N, Wunsch H. Evidence supports the superiority of closed ICUs for patients and families: we are not sure. *Intensive Care Med*. 2017;43(1):128-30.