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Nursing essential principles: continuous renal replacement therapy

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ABSTRACT

Aims: This article aims to guide critical care nurses with the care and management of patients on continuous renal replacement therapy (CRRT).

Background: CRRT, a highly specialized therapy involving complex nursing care, is used widely in the intensive care unit to treat patients with acute kidney injury.

Methods: A literature search was conducted using CINAHL, Medline from PubMed and BNI using the search terms CRRT or continuous veno-venous haemofiltration and nursing or nurses from 2000 onwards and limited to the English language. The appraised evidence and expert opinion is used in this article.

Results: Four essential nursing principles for CRRT are reviewed (1) the importance of continuous assessment of the indications to influence the appropriate mode; (2) ensuring good vascular access; (3) the avoidance of unnecessary interruptions and (4) the prevention of complications.

Conclusion: The identified four essential nursing principles provide guidance on this complex aspects of nursing practice. Specific nursing research to guide the care and management of this therapy is limited so should be explored in the future.

Relevance to clinical practice: Critical care nurses caring for and managing patients on CRRT require an understanding of how to deliver safe CRRT.

Key words: Acute kidney injury • Continuous renal replacement therapy (CRRT) • CRRT circuit • Essential principles

INTRODUCTION

Acute kidney injury (AKI) is a common complication of critical illness occurring in 25–65% of the critically ill and 5–8% of these patients require some form of renal replacement therapy (Albarran, 2012). Continuous renal replacement therapy (CRRT) is a continuous treatment option widely used in the intensive care unit (ICU) to treat AKI in the haemodynamically unstable critically ill patient, as it removes fluid and waste products from the patient's blood gradually and continuously. CRRT is highly specialized and the nursing work involved in CRRT is complex (Langford *et al.*, 2008).

Recent CRRT publications have focussed on the complexities of AKI staging and classification (Lewington and Kanagasundaram, 2011; Kellum and Lameire, 2013) and optimal filtration doses (Younker, 2012). These important developments have had positive implications for the treatment of patients on CRRT; however, specific guidance for the ICU nurse to assist in managing and maintaining CRRT is limited.

In the UK, the ICU nurse's role in the care and management of CRRT is important as they are the professional who generally starts, monitors, assesses and discontinues the therapy. In addition, the ICU nurse is responsible for providing 24-h bedside observation and care to support the patient on CRRT. These important nursing roles and responsibilities provide the rationale for this review of the literature, which aims to provide detailed guidance on the essential nursing elements required for safe and effective care for patients on CRRT.

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METHODS

Three electronic databases (Cinahl, Medline from PubMed, BNI) were searched to identify citations relating to nursing management and care of CRRT. Only English language articles published since 2000 were included. The following key words, acronyms and combination of terms were used: continuous renal replacement therapy (CRRT), continuous veno-venous haemofiltration (CVVH), nursing and nurses. In addition, information was requested from manufactures of CRRT machines available within the UK.

The literature search uncovered an extensive number of papers, however, those relating to nursing management and care of CRRT were limited. Owing to the lack of published research on nursing care, expert opinion on best practice is utilized alongside the reviewed and appraised papers.

ESSENTIAL PRINCIPLES FOR NURSING CARE AND MANAGEMENT OF CRRT

Four essential nursing principles were identified from the literature (Table 1).

Continuously assess the indications for CRRT and influence the appropriate CRRT mode

There are a number of indications for CRRT and some patients have more than one indication. For example, a patient in severe sepsis and AKI may well be acidotic, fluid overloaded and have a high blood potassium. Alternatively, some patients may require CRRT for a single reason such as cardiac failure resulting in fluid overload.

It is important for the critical care nurse to assess the indications for CRRT and understand how CRRT can provide the necessary treatments for each indication (Table 2).

In addition to the assessment of the indications for CRRT, the nurse's role is to understand the CRRT modes available. The same CRRT mode is often used to treat all patients for a number of varied indications. For example, in the UK CVVH is the typical mode used with little consideration for other more appropriate modes for each individual patient and their indications. This can result in patients with different indications receiving the same type of CRRT. The critical care nurse should have an understanding of the different types of CRRT available in order to recommend and influence the choice of treatment type to best match the individual CRRT patient indication.

Richardson and Whatmore (2013) outline four main modes of CRRT, their principle action and indications for the use of each (Table 3).

Good vascular access

Vascular access is usually provided via a dual lumen central venous catheter (CVC)**.** Good blood flow to and from the CVC is important as poor patency can result in the CRRT circuit stopping intermittently; subsequently reducing treatment time. Slow flowing or static blood is likely to clot more quickly. Therefore, the nurses have an understanding of the factors which affect blood flow and how to minimize problems:

Table 1 Four CRRT essential nursing principles

	Essential principles
1.	Continuously assess the indications for CRRT and influence the appropriate CRRT mode
2.	Good vascular access
3.	Avoid unnecessary interruptions to CRRT
4.	Prevention of CRRT complications

CRRT, continuous renal replacement therapy.

Catheter choice

The ability to maintain good vascular access starts with appropriate catheter choice and this is usually achieved with a large bore (12 Fr) double lumen CVC in a large central vein (Sarkar, 2009). Common sites include internal jugular, femoral or subclavian veins. The length of the CVC is also an important choice ranging between 15 and 24 cm. The shorter lengths are more suitable for the internal jugular site and the longer lengths for femoral and subclavian sites.

Catheter securement

The CVC should be well secured to the patient to prevent accidental removal. This can be achieved by using a suture and a dressing (Baldwin and Fealy, 2009).

CVC blood flow check

Prior to commencement of CRRT it is important to ensure good blood flow from the double lumen is present (Richardson and Whatmore, 2013). Good patency is indicated if blood easily fills the syringe when blood is withdrawn from the CVC (Dirkes and Hodge, 2007).

Actions to improve blood flow

If adequate blood flow during treatment cannot be achieved then the following actions may be necessary:

- Observe the CRRT circuit to ensure that there are no tubing kinks or occlusions
- Ensure clamps on the CRRT circuit are off
- Check the position of the patient as sitting up and side lying may result in an internal kink in the CVC and reduce blood flow.

Table 2 Indications for CRRT and CRRT mechanisms

Indication for CRRT	CRRT mechanism
Fluid overload	Removes plasma water as programmed to achieve desired fluid balance
Maintain cardiovascular instability	Avoids rapid changes in fluid levels due to the continuous process
For uremic and electrolyte control	Corrects electrolyte abnormalities and removes waste products
For metabolic control	Corrects metabolic acidosis
To prevent and treat raised Intracranial pressure	Removes plasma water to reduce intracranial pressure or prevent increased intracranial pressure
To treat Severe Sepsis	Removes or absorbs many of the soluble inflammatory mediators of sepsis and for temperature control
To remove intoxications	Removes non-protein bound intoxications

CRRT, continuous renal replacement therapy.

Table 3 Types of CRRT (adapted from Richardson and Whatmore, 2013)

Type	Method	Principle action	Indications
Slow continuous ultrafiltration (SCUF)	Patient is attached to the CRRT machine and their blood is pumped through the haemofilter.	• Ultrafiltration	• Fluid overload without uraemia or significant electrolyte imbalance e.g. cardiac failure.
Continuous veno-venous haemofiltration (CVVH)	Patient is attached to the CRRT machine and their blood is pumped through the haemofilter with replacement fluid (balanced physiological electrolyte fluid) added either before or after the filter	• Ultrafiltration and convection	• Uraemia • Severe acid-base or electrolyte imbalance with or without fluid overload
Continuous veno-venous haemodialysis (CVVHD)	Patient is attached to the CRRT machine and their blood is pumped through the filter with dialysate running in a counter current flow, in the outside compartment of the haemofilter	• Ultrafiltration and diffusion	• Removal of fluid and small to medium sized molecules, in patients with severe uraemia, acid base and electrolyte imbalance.
Continuous veno-venous haemodiafiltration (CVVHDF)	Patient is attached to the CRRT machine and their blood is pumped through the filter with dialysate running in a counter current flow, in the outside compartment of the haemofilter and replacement fluid is pumped in after the filter	• Ultrafiltration, Diffusion and convection	• Enhancing metabolic control if this is not being achieved with CVVH

CRRT, continuous renal replacement therapy.

- Ensure the pump speed is appropriate (not too fast) for the CVC bore to avoid unnecessary sucking on the vessel wall.
- Reverse the access and return lines. Even though reversal of the lines can result in a small reduction in clearance due to some internal recirculation, maintenance of the circuit life is the priority (Sarkar, 2009).
- If blood flow is still inadequate consider changing the CVC.

Access and return pressure monitoring

Access and return pressures are affected by the patency of the circuit and the blood pump speed. Hourly monitoring of access and return pressures on the CRRT machine is a way of assessing the blood flow within the CVC once CRRT has started. Trends in pressures will enable the detection of access problems (Dirkes and Hodge, 2007). The access pressure monitors the negative pressure generated to remove blood from the patient, therefore generally when blood flow is reduced the access pressure drops. The return pressure monitors the positive pressure generated to return blood to the patient; therefore, if the pressure is raised the return of blood will be difficult.

Flushing the CVC when not in use

When CRRT is discontinued both lumens of the CVC should be flushed. This procedure prevents thrombi forming within the lumen when not in use (Sarkar, 2009). The double lumen catheter should be flushed with 10 mL of 0·9% sodium chloride and then, according to local policy, anticoagulant administered as prescribed once disconnected from CRRT (Richardson and Whatmore, 2013).

Avoid unnecessary interruptions to CRRT

To preserve the life of a CRRT circuit and to maximize the effectiveness of the therapy it is important to avoid unnecessary interruptions. A number of key therapy choices and nursing actions can influence the life of the CRRT.

Ensure adequate blood pump speed

A blood flow above 100 mL/min reduces the possibility of thrombus forming in the circuit (Davies and Leslie, 2006). Therefore, once adequate access is established setting and maintaining the CRRT pump speed at a rate fast enough (usually between 150 and 200 mL/min minute) to prevent thrombus formation in the circuit is important.

Higher blood pump speeds reduce the filtration fraction which is a measure of haemoconcentration and should generally be kept below a value of 25% if using a post-dilution mode (Joannidis and Oudemans-van Straaten, 2007).

Choice of anticoagulation

Anticoagulants maximize circuit life by preventing blood from clotting in the extracorporeal circuit. Many types of anticoagulation can be used and the choice of agent will depend on a patient's condition, the action of the anticoagulant and its relative benefits and limitations. For patients without an increased bleeding risk or impaired coagulation regional citrate anticoagulation is suggested rather than heparin in patients who do not have contraindications for citrate (KDIGO, 2012).

Table 4 summarizes the main types of anticoagulants, their benefits, limitations and the associated nursing actions.

Some patients who have a high risk of bleeding due to a coagulopathy may not require anticoagulation (Dirkes and Hodge, 2007).

Consider pre-dilution

Replacement fluid can be added before the haemofilter (pre) or after (post) the haemofilter. Increasing pre-dilution rates may prolong the life of the filter (Richardson and Whatmore, 2013) by reducing the blood haematocrit (i.e. reducing filtration fraction). This is thought to diminish clearance, however, studies have compared pre- versus post-dilution and daily creatinine changes were not significantly different. This outcome is possibly due to the reduced filter downtime (Joannidis and Oudemans-van Straaten, 2007).

Observing the circuit for clots

Predicting filter clotting is an important nursing role as it is desirable to return blood from the circuit to the patient before clotting and complete obstruction of the circuit (Baldwin and Fealy, 2009). This prediction requires constant observation of the CRRT circuit for the presence of clots. This includes observation of the circuit pressures as a rise is an early indication that thrombi are within the system (Dirkes and Hodge, 2007). Some nurses check the filter and circuit for visible clots after a saline flush (200–300 mL) but this method is not considered as reliable as circuit pressure measurements (Baldwin and Fealy, 2009). On occasions, the CRRT circuit lines can begin to move just before the filter clots, often referred to as 'jumping'. If clots occur, the CRRT circuit will not function and at this point it is desirable to return the blood to the patient prior to complete obstruction (Baldwin and Fealy, 2009).

Responsive problem-solving of the circuit alarms

The circuit alarms are set to alert nurses to changes in pressures within the circuit. It is important to understand and respond to the cause of the alarm quickly to maintain the CRRT. Davies and Bench (2011) outline the main alarms by type, causes and remedy (Table 5).

Prevention of CRRT complications

CRRT is an extracorporeal process (blood circulating outside the body through an artificial filter), which carries risks and complications. The prevention of complications is an important part of the nursing management and care of patients. The potential complications are detailed below along with nursing guidance to aid the avoidance of their occurrence.

Air embolism

The purpose of priming the circuit is to remove all air before connecting the patient and commencing treatment (Faber and Klein, 2009). Priming the CRRT circuit is usually undertaken with 1 L of 0·9% sodium chloride with or without heparin dependent on the patient's condition. There is an air detector in the system, however, nurses should be constantly alert for signs of an air embolism (e.g. loose connections) and know what to do in the event of occurrence.

Drug removal

CRRT can remove some drugs, such as antimicrobials through the filter. The amount of which will vary according to the type of CRRT and the ultrafiltration rate (Levy *et al.*, 2009). Therefore, adjustments to prescriptions and administration of drugs need to be considered (Schetz, 2007). In addition, if CRRT is stopped, prescribers should be made aware so that further drug adjustments can be made (Levy *et al.*, 2009).

Electrolytes and metabolic imbalance

As CRRT removes fluids, it also removes electrolytes in an unselected way. It is important therefore,

Table 4 Types of anticoagulants

Anticoagulant	Action/how it works	Benefits	Limitations	Nursing actions
Heparin	Binds to antithrombin III to inhibit thrombin and factor Xa to prevent clot formation (Davies and Leslie, 2007). Commonly used in the priming solution as it may adhere to the plastic of the circuit lines and filter membrane (Davies and Leslie, 2007).	Least expensive (Dirkes and Hodge, 2007). Can be administered systemically if there is pre-existing requirement for anticoagulation – such as in patients undergoing treatment for a pulmonary embolism.	Risks of haemorrhage, heparin resistance (patients requiring greater than 35 000 units of heparin/day to achieve the therapeutic range) (Anderson and Saenko 2002) and heparin-induced thrombocytopenia.	Regularly measure the 'Activated Partial Thromboplastin Time' (the time taken in seconds for a clot to form) (Chacko 2008). Activated Partial Thromboplastin Ratio (APTR) Test result should be used to titrate heparin dosage according to local protocols and within prescribed limits. Generally the desired APTR target range is between 1·5 and 2·5.
Prostacycline	Prevents platelet aggregation. It does not affect the clotting pathway. Dose is gradually increased as per patient weight.	Reduction in incidence of bleeding. Can be used in combination with a reduced dose of Heparin to extend filter life. No need to measure APTT and titrate dose (Davies and Leslie, 2006).	Associated with vasodilation and unwanted hypotension.	Slow increase to maximum dose as per patients' weight. Close observation of cardiovascular status due to vasodilatory effect.
Regional citrate	As calcium is an essential part of clotting, Citrate binds to calcium within the circuit thus interrupting the clotting cascade and preventing clotting. Citrate is infused prefilter and calcium is infused post filter (Dirkes and Hodge, 2007).	Avoids systemic anticoagulation and prevents bleeding. Increased circuit life (Kutsogiannis *et al.*, 2005).	Requires diligent monitoring of calcium levels and metabolic status to avoid metabolic alkalosis and hypocalcaemia (Davies and Leslie, 2007). May be contraindicated in liver failure, as these patients may not be able to metabolize citrate (Dirkes and Hodge 2007).	Regular monitoring of electrolytes and ph and adjustments required to calcium infusion.
Thrombin Inhibitors eg argatroban and lepirudin	Directly inhibit thrombin, often used in patients with heparin-induced thrombocytopenia (HIT) (Dirkes and Hodge, 2007)	Can be used in patients with HIT.	Limited clinical experience. Thrombin inhibitors can accumulate in patients with AKI, causing levels to elevate, thus increasing the risk of bleeding (Davies and Leslie, 2007).	ECT (ecarin clotting time) needs to be monitored for dose adjustment, this is not always available. (Davies and Hodge, 2007).

to closely monitor and replace electrolytes in the ultrafiltration replacement fluid as required (Culley *et al.*, 2006). Therefore, important nursing roles are to:

- test the patients' systemic blood for electrolyte imbalance prior to changing replacement fluid bags and at regular intervals (4–6 hourly). The correct dosage of additional electrolytes can then be added and administered (Richardson and Whatmore, 2013).
- increase frequency of electrolyte testing if electrolyte levels are outside normal ranges (Richardson and Whatmore, 2013).
- titrate the administration of potassium using an algorithm where dose is dependent on concentration in the blood (Brooks, 2006).
- monitor phosphate levels and replace, where appropriate, to prevent low serum phosphate levels (Bellomo and Ronco, 2000).
- monitor arterial blood gases for pH balance, base excess and increase in lactate. The CRRT settings can then be altered by increasing or decreasing the ultrafiltrate rates or changing the mode of therapy to address the imbalance (Dirkes and Hodge, 2007).

Haemodynamic instability

An accurate assessment of fluid balance and haemodynamic status is important prior to commencing and during the CRRT. Inaccuracies in fluid management can result in either under or over hydration of the patient (Mehta, 2001) and this can lead to hypovolaemia causing significant drops in blood pressure

Table 5 CRRT alarms, causes and remedies (adapted from Davies and Bench, 2011)

Alarm type	Possible causes	Possible remedy
Venous pressure too high	Clot in return line of circuit, drip chamber or CVC Line kinked or clamped or against vessel wall	Relieve obstruction Ensure all clamps open Check lines not kinked of clamped Change patient position
Access pressure too negative	Inadequate blood flow from access port Obstruction Line kinked or clamped or against vessel wall	Access and return may be temporarily switched Discontinue, wash back if possible Reposition vascular access
Access pressure not negative enough	Additional infusions pre-blood pump	Stop and reduce infusion rate of pre-blood pump fluids
Return pressure too low	Disconnection or loose connection Low pump speed	Tighten all connections Check lines – keep visible Increase pump speed
High pre-filter pressure	Filter clotting (gradual increase)	Reduce post dilution and increase pre-dilution Alter blood flow rate to reduce filtration fraction
High trans membrane pressure (TMP)	Blood flow to exchange ratio too high	Alter blood flow rate and/or replacement fluid/exchange rate
Air detected	Disconnection Air chamber not correctly positioned Blood level too low Turbulence in chamber	Check line Clamp access and return lumens Re-position drip chamber Raise fluid level in chamber If large amount of air, disconnect and prime new circuit.
Fluid balance	Bag swing Obstruction to floor	Try to avoid knocking bags Ensure all connections are open Relive any obstructions Avoid repeatedly overriding this alarm as can lead to incorrect volumes of fluid removal
Blood leak detected	Damaged filter (ultrafiltration pink in colour)	Discontinue and set up new lines

CRRT, continuous renal replacement therapy.

(Dirkes and Hodge, 2007) or hypervolaemia causing fluid overload. Important nursing roles are:

- Prior to commencing CRRT undertake a full assessment of the following:
  - Fluid status including all intake and output
  - Baseline observations of blood pressure, heart rate, cardiac rhythm, central venous pressure, cardiac output (if being measured)
  - Dosages of vasopressor drugs being administered.
  - Weight and an agreed fluid balance goal should be set (Dirkes and Hodge, 2007; Richardson and Whatmore, 2013).
- During CRRT undertake the following:
  - Calculate the patient's fluid balance on an hourly basis. Intake includes infusions, medications and nutritional input. Output includes urine, sweating, nasogastric/bowel loss and drain/wound loss.
  - Consider the actual and desired fluid balance and programme the CRRT machine for the desired hourly volume removal.
  - Continually assess blood pressure, pulse, heart rate, central venous pressure and cardiac output/pulmonary artery pressures as available.
  - Ensure replacement fluids are prescribed and notify the CRRT prescriber of any adverse effects due to fluid loss. (Dirkes and Hodge, 2007; Richardson and Whatmore, 2013).

Hypothermia

A typical CRRT extracorporeal circuit contains 110–200 mL of blood outside the body. This can cause hypothermia (Dirkes and Hodge, 2007). Therefore important nursing roles are:

- Four hourly monitoring of patients temperature
- Warming of the replacement and/or dialysate fluids prior to entering the CRRT circuit or blood lines.
- Adjustments of replacement and/or dialysate fluid temperature on the CRRT machine
- Use of warming blankets and/or consider increasing the temperature of the room (Dirkes and Hodge, 2007).

Infection

A blood stream infection can be caused by entry of bacteria via the CVC (Loveday *et al.*, 2014). To minimize this complication, the following nursing roles should be considered with the ongoing care of a patient on CRRT:

- The IV access should be dedicated for CRRT single use (Faber and Klein, 2009) and only used for other purposes in life-threatening situations (Sarkar, 2009).
- A sterile, transparent, semi-permeable dressing should cover the CVC and be changed every 7 days or sooner if it is no longer intact (Loveday *et al.*, 2014)
- Any manipulations to the circuit should be done using aseptic non-touch techniques and principles.

Nurses should ensure that they follow local personal protective equipment (PPE) procedures to ensure they protect themselves from the risk of exposure to blood and other body fluids, and reduce the opportunities for transmission of microorganisms from staff to patient and vice versa. Depending on the activity or procedure being undertaken consideration should be taken for the appropriate use of gloves, aprons, masks, goggles and visors.

Nutrition

Patients in AKI often experience problems with electrolyte balance, fluid balance and malnutrition resulting in nutritional challenges. Therefore, it is important to undertake a thorough nutritional assessment of patients with AKI on CRRT to formulate an appropriate nutrition prescription (Kalista-Richards, 2012).

CONCLUSIONS

Critical care nurses have 24-h responsibility for care and management of patients receiving CRRT. There is limited published literature, which guides the nursing care and management of the patient receiving CRRT and more research is required to provide robust evidence for nursing practice.

On the basis of the currently available evidence, this review has identified four essential nursing principles to guide nursing practice. The first principle focuses on the value of careful and continuous patient assessment to ensure that the patient receives the most appropriate mode of CRRT. Many patients remain on the same mode throughout their requirement for CRRT; however, the nurse is ideally placed to influence decisions about the most appropriate mode for each individual patient. The importance of good vascular access is the second principle, and although the insertion of the CVC is not usually a nurse's role, other aspects such as patient position and monitoring the vascular access are critical nursing roles. The third principle highlights the significance of nursing actions to avoid unnecessary interruptions. The avoidance of these interruptions enables the patient to receive maximum therapy. As CRRT is a complex extracorporeal process, the fourth principle identifies the main complications associated with CRRT such as haemodynamic instability, infection and hypothermia. Important nursing actions to minimize these complications are identified to maintain patient safety.

Due to the limited literature focussing on nursing care and management, more research should be undertaken to provide robust evaluation of CRRT nursing actions in the future.

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WHAT IS KNOWN ABOUT THIS TOPIC

- CRRT is used widely in the intensive care unit to treat patients with acute kidney injury.
- CRRT is a highly specialized therapy and the nursing care is complex.
- Critical care nurses have the 24-h responsibility for care and management of patients on CRRT.

WHAT THIS PAPER ADDS

- On the basis of the currently available evidence, this article provides a review of the essential nursing principles to guide the nursing care and management of patients on CRRT.

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