CHAPTER 162

Nursing Issues and Procedures in Continuous Renal Replacement Therapy

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OBJECTIVES

This chapter will:

1. Discuss and suggest suitable nursing lectures, tutorials, and a practical pathway for continuous renal replacement therapy (CRRT) nursing knowledge and competency.
2. Describe the suitable items and content for policy and documents used to manage CRRT.
3. Highlight the importance of the anticoagulation section in the policy.
4. Describe suitable CRRT machine attributes and their improved functionality.
5. Outline the importance of quality measures and the multidisciplinary team for CRRT success.
6. Briefly comment on the expanding use of CRRT in the operating room and for extracorporeal membrane oxygenation and advanced therapies such as plasma exchange.

Nursing requirements for continuous renal replacement therapy (CRRT) in the intensive care unit (ICU) are challenging and time sensitive, mandating a comprehensive education and training pathway. This is achievable when lectures and tutorials are combined with practical learning and live patient experience. Training about the machines used for CRRT and their evolving automation and interface makes the education challenge easier. Policy and procedure documents and electronic resources are important training topics with a focus on anticoagulation method. This aspect of CRRT may be problematic unless the prescription is clear and nurses are able to associate knowledge with hands-on experience. There are many quality ideas, but attention to filter life or time of CRRT effective delivery and achieving fluid balance are priorities with both linked to nursing expertise and competency for CRRT. The team approach is paramount, in which many disciplines involved with CRRT must meet and can be led by a nurse as champion of CRRT in the ICU. This provides necessary continuity, communication in a busy environment, and, when changes are needed, provision of feedback. Nursing needs for CRRT with extracorporeal membrane oxygenation (ECMO) and the operating room (OR) are progressing with guidance from limited literature. Advanced therapies broadly described as blood purification are possible when the basics are consolidated. This chapter provides a brief discussion for these aspects of CRRT in the ICU.

NURSING KNOWLEDGE AND ACUTE KIDNEY INJURY

The application of lifesaving and supporting devices in the ICU requires human, technical, and educational resources for safe and efficient use by nurses. Respiratory and cardiac support are foundational curriculum for nurses training in critical care mostly because of their commonality and life-sustaining constant use with immediacy of nursing attention and care requirements (e.g., the artificial airway and mechanical ventilators or the maintenance of vasoactive drugs and cardiac pacemakers). CRRT, however, may be required less frequently and sporadically, making the association between base level training and lectures and patient care experience unreliable. Therefore practice and simulation activities are helpful when long periods of time elapse between patient care experiences.[1,2] However, with increasing use of CRRT in busier referral centers, this new knowledge and practical skill sets are better linked and mandate an expansion of the core curriculum for nursing in the ICU to include CRRT competency development with equal importance to use of a ventilator or monitoring system.

As for other ICU technologies, learning to use the machine or technology is the end point, but this always must be preceded with background education for the "who, why, and how" approach.[3,4] Theory or didactic classes should be provided before any practical machine use. This may appear to slow the road towards bedside competency. Furthermore,

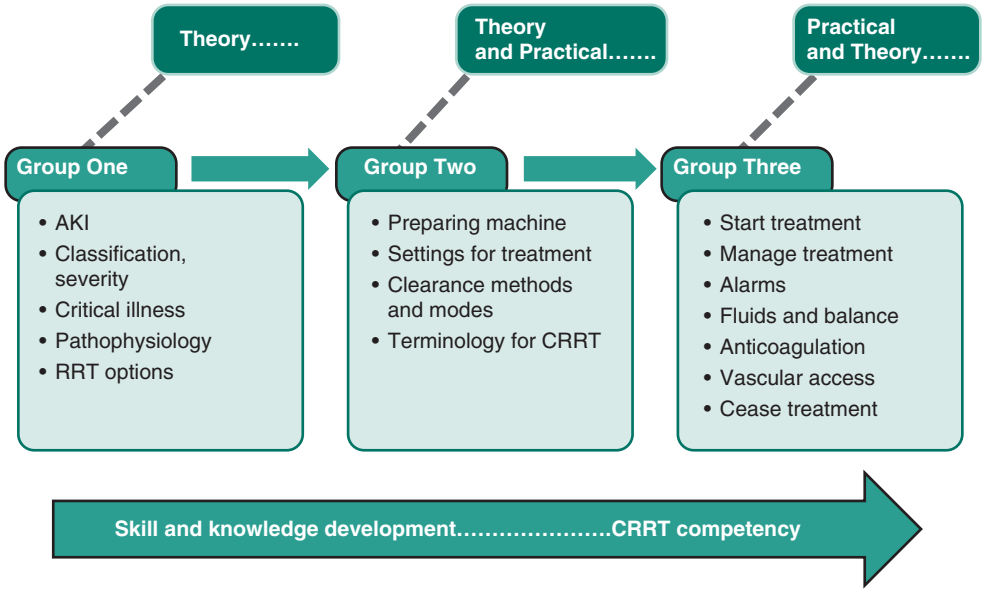


FIGURE 162.1 Concept map for grouped tutorials and lectures suitable to provide CRRT nursing knowledge and practical competency for care of the critically ill with acute kidney injury.

it may be questioned because ICU nurses are usually eager to start using the CRRT machine (or any new technology) with a desire to "master" this, as with the mechanical ventilator, pacemaker, or hemodynamic monitor. Therefore theory must precede some practical experiences, and learning must be in a skill development ladder.

GROUP ONE LECTURES

To begin, current understanding and key concepts of acute kidney injury (AKI) and critical illness are necessary first lectures in the knowledge and skills pathway for CRRT competency and nursing mastery of this therapy. Classes should provide an understanding of acute kidney failure: how this illness manifests, relevant physiology and pathologic changes, classification for severity, association with other organs and their failure during illness, likely prognosis, and best treatment strategies for renal replacement therapy (RRT) options and different modes. Figure 162.1 indicates this as a concept map for grouped tutorials or lectures suitable to provide this nursing knowledge and practical competency for care of the critically ill with AKI.

GROUP TWO TUTORIALS AND PRACTICAL ONE

When the key aspects of AKI and treatment are presented and learned, CRRT and the devices used are the next step in the pathway to competency and safe patient care. Before this machine training, dialysis mechanisms for waste and fluid removal must be taught in lecture or tutorial format. These are the concepts of diffusion, convection, ultrafiltration, dose, and the extracorporeal circuit(s) to achieve these.[5,6] This training begins to reveal and describe important terminology and key language for CRRT vital for later clinical experience, prescription orders, and safe care to patients. These lectures may be linked to machine training at this point. With associated priming, the circuit and setup as theory and practical aspects of machine training fit together well in concept, terminology used,[7] and the psychomotor skills[4,8] required. This describes group two lecture or tutorials in Fig. 162.1.

GROUP THREE TUTORIALS AND PRACTICAL TWO

Group three tutorials are designed to consolidate further the use of a prepared CRRT machine and are associated with the connection to patient procedures, monitoring, and settings for a treatment in progress and those for ceasing and terminating CRRT. This third stage is scheduled optimally concurrent with live patient experience. The relevant lectures and tutorials at this time are focused on fluids used, fluid balance, anticoagulation, and the vascular access device. The links from theory or abstract are more logical, faster, and easier learned if nurses can see this in action and real time with a patient in their care experience. This approach does mandate that the learners are supported during the patient care aspects by an experienced CRRT competent nurse possibly in the adjacent bed-patient or in a location to help, teach, oversee their learning, and decision making.[9] In some ICUs clinical educators provide this support and have this dedicated support role. This is a nursing apprentice context and is well established in the ICU for new learners with other technologies and interventions such as ventilation, monitoring, and major surgical care such as postcardiac or neurosurgery.

Sequence and logical progression is therefore evident from pathophysiology of AKI, dialysis clearance processes, circuits for treatment, language and key terminology, fluids and balance, vascular access catheter, anticoagulation, and then practicum of circuit preparation and machine operation. CRRT circuits for each mode or option have been well described in the literature since at least the early 1990s.[3–9] They are not presented again here but will be viewed in other chapters describing CRRT modes, circuits and machines

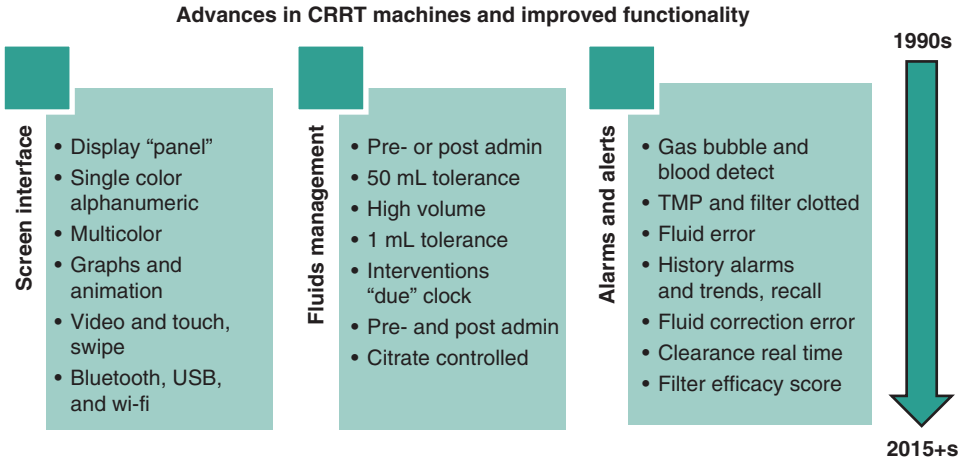


FIGURE 162.2 Timeline for advances in continuous renal replacement therapy technology.

used. Theory before practical, simple to complex, abstract to concrete is the best advice.

CERTIFICATION AND CONTINUOUS RENAL REPLACEMENT THERAPY

The curriculum necessary to educate and train nurses as competent users and managers of CRRT in the ICU is not clear; however, publications have described approaches with or without links to a nephrology department.[2,10–13] CRRT machine vendors have established teaching and training programs for nurses primarily for their machines designed for small groups or whole ICU staffing cohorts when a new machine is installed. These classes may award nurses a certificate of completion, and there may be workshops or other nursing classes provided in association with scientific and society meetings awarding similar completion status. However, there is no recognized qualification for CRRT competency, and this is usually supplemental training to the many ICU registrations and certifications worldwide. There is variability with certification in the United States, overseen by the American Association of Critical Care Nurses (AACN).[14]

CONTINUOUS RENAL REPLACEMENT THERAPY MACHINES

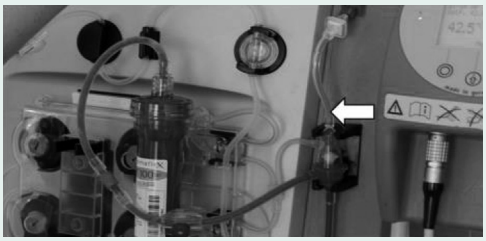
The machine or device for CRRT is different from a dialysis machine, which uses a connection to reverse osmosis water as a continuous high-volume supply throughout treatment. CRRT uses commercial fluids prepared in large bags and requires frequent changing and resupply during use along with empty of the equivalent waste fluid generated.[15–17] Approximately 8 to 10 5-L bags per 24 hours are needed for an adult weighing around 80 kg. As a result, and differentiating the CRRT system are weighing scales as a method for determining fluid flow rates used and importantly fluid balance; the full bags empty, losing weight, and the waste bag fills, gaining weight with any difference between these weights equating to the machine fluid balance. The CRRT device is accompanied by its own circuit tubing kit relevant to the machine manufacturer. Fluid bags and the membrane or hemofilter used may be interchanged across manufacturers in some cases. The latest design has focused on faster and increased automation in preparation and kit priming, extending battery functionality for unexpected main power loss, and enabling moving the machine power line while treating and limited patient transport using the machine. New and increased simplicity during use is provided for display and adjustment of settings, multimode or clearance technique change during treatment, and new smart software design for the provision of citrate anticoagulation.[18]

Gas bubble detection, circuit pressure monitoring to indicate blood flow failure, warning for clot and clogging development in the membrane, and fluid balance error are foundations basic and common to all machines historically.[19,20] Training prompts, video, and pop-up text are also being introduced and can be helpful for bedside education and troubleshooting. Choosing a machine is a necessary step for a CRRT program and is a common question and discussion point among ICU nurses and physicians. Figure 162.2 provides an evolutionary development of options and automation for CRRT machines, recognizing practical, simple, and advanced aspects of more recent offerings toward the future.

Key nursing management and tasks for CRRT are provided in Table 162.1 for the basics of routine nursing attention and maintenance of a treatment. The essential and overall role for the nurse is summarized here in two domains: (1) monitoring and (2) preparation, connect and disconnect. The following represent some of the work associated with the nursing care required: monitoring correct machine function for reliable flow of blood, continuous changing of bags as substitution fluids empty and waste bags fill, adjustment and constant review for stability with anticoagulation agents used, and then the overall monitoring and response to other patient metabolic stability with electrolyte, acid base, and temperature management. [3,6,9,11,21] Machine and circuit preparation, connection, and when required, stopping and disconnecting a treatment are further skill and knowledge sets for ICU nurses.[3,8,20] Consideration of all these factors represents why nurses are particularly concerned that a new treatment, when started, is stabilized and then functions continuously for as long as possible. This perspective is an additional consideration to the medical aims of treatment, ensuring solute, acid base, and fluid balance is controlled. It is of key interest of doctors and nurses in the ICU that a treatment be "continuous," because frequent stopping and restarting is a lot of work for nurses and may cause instability with the patient.[22,23]

TABLE 162.1

Key Nursing Skills for CRRT

NURSING AREA FOR CRRT	KEY NURSING TASKS REQUIRED (PREPARATION AND MONITORING)
• Patient and machine preparation and starting treatment. • (See photos below indicating asepsis for connection of circuit and self protection for operators - nurses)  	• Machine test or checklist completed • Double-check all connections in circuit • Treatment orders re- checked • Double-check fluids used, any additives? • Asepsis connection of circuit, use slow blood flow until stable • Asepsis and self protection
• Troubleshooting and maintenance. • (See photos below indicating checking of settings, alarm messages, and circuit pressures along with circuit and evidence of clotting.)  	• Blood pump, alarms set, machine brake on • Secure circuit lines and with access catheter • New fluids bags ready • Venous chamber filled correct level, bubbles removed • Heater set for fluids or blood line warmer to 37°C
• Monitoring and adjustment for anticoagulation	• e.g. Heparin or Citrate, follow protocol. Lab orders, and infusion adjustment
• Accessing catheter care and dressings	• Dress according to local policy; prevent infection and line displacement or dislodge
• Vital sign monitoring • (see photo below showing patient vital signs displayed on bedside monitor) 	• Monitor vital signs, consider association between any changes and use of CRRT; e.g. CVP or other haemodynamics, temperature, SaO^2

Continued

TABLE 162.1

Key Nursing Skills for CRRT—cont'd

NURSING AREA FOR CRRT	KEY NURSING TASKS REQUIRED (PREPARATION AND MONITORING)
• Assessing filter function • (see photo below showing screen 'status' display on Prismaflex machine) 	• If transmembrane pressure (TMP) or prefilter pressure (P-IN) >250 mmHg, consider electively ceasing treatment.

Key nursing skills for CRRT as two essential domains: 1. monitoring, 2. preparation.

PROTOCOLS AND DOCUMENTS FOR CONTINUOUS RENAL REPLACEMENT THERAPY

Policies as paper documents at a bedside are being replaced by electronic versions via clinical e-information systems and computer interface. However, for prescribing, safety checks, and some setup procedures, paper versions remain useful and practical particularly when they include pictures and associated simple messages and prompts for remedy. Examples of policy and procedure documents are published previously and vary in detail, but key elements are for machine setup and circuit preparation methods, connection of the circuit and starting treatment, maintenance of a treatment and what to monitor, troubleshooting problems and alarms, timing and method for ceasing a treatment, and care of the access device.[3,6,9,10,20]

The key focus and more detailed section within policy documents is the anticoagulation method used, because this is a frequent reference and cross-check point for clinicians during use, and at nursing handover and medical rounds. This aspect of CRRT is detailed and targeted to reduce mistakes because it is probably the most hazardous. The consequence of error and miscommunication is bleeding. The larger surrounding document can also be designed to close any gaps between machine manufacturer instructions for use and the clinical aspects of the specific prepared CRRT machine. Sometimes physician prescribing and nursing models can mandate deviations from that indicated by the manufacturer recommendations or where lengthy text is in an operator manual, paper documents as two or three labeled diagrams in a local policy document may be printed and used for each patient use. For example, how to connect and start treatment, when to change a circuit, stopping treatment, the diagnosis of clotted circuits, and fluids and blood flow prescribing may vary from the instructions for use in an operator manual.

ANTICOAGULATION

Because anticoagulation is a common source of question and communication error, and it varies across hospitals even within the same method, a brief summary is useful here. Readers are referred to the dedicated chapters for this topic. The use of anticoagulation, although not mandatory when prescribing CRRT, the extracorporeal circuit (EC) life will be improved with use.[24,25] Recent evidence supports the use of citrate,[26,27] the preference in many healthcare centers. As an alternative or first choice, heparin is administered into the circuit blood pathway before the membrane and is dosed to elevate the activated clotting time to a level close to or within therapeutic range for the local hospital lab. Many clinicians are familiar with heparin and have used this drug for other medical indications. The dose and patient response in the critically ill are variable, and antibodies to heparin can make this method ineffective.[28–30] Low-molecular-weight versions of heparin are also used. However, unfractionated heparin can work well and is reversible with protamine administration.[31] Citrate, in contrast, has the benefit of anticoagulating the circuit alone, protecting the patient from altered coagulation, and providing a buffer when the administered citrate returns to the general venous circulation and is converted to bicarbonate after liver metabolism.[32,33] The cornerstone of safe use is to restore the systemic ionized calcium level for the patient as citrate chelates or removes calcium from the plasma, and much of the newly formed molecule is lost via the CRRT waste.[33] The prefilter citrate dose via infusion or as a fluid additive must be considered in association with the blood flow used for any given CRRT prescription, because this mixture and concentration must reduce the EC ionized calcium to around 0.3 to 0.5 mmol/L for best effect.[32,33] This can be achieved with protocols in a given hospital, and although some variation is evident for the exact method and monitoring frequency, they are similar.[33] Recently machine design and software has adopted the management of citrate method to link the citrate dose (added to fluids, or via concentrate infusion), blood pump speed, and the measured ionized calcium (lab check and input required). This software link automatically performs the technique without the use of reference charts or human decision making for adjustment (e.g., when fluids and blood pump speed changes are made during CRRT).[18] This technology option appears safe and effective with inherent time saving and quality control. However, clinicians must pay attention to the correct use of the setup procedures, software alerts, and necessary propriety fluids (citrate mixture) relevant to the specific machine and supplier. Limited experience reports[18] reflect single centers or case examples. Larger data pool evaluations will be useful to validate and better inform advances in this technology with the possibility of other

settings and prescriptions during CRRT to be controlled by intelligence software (e.g., dose adjustment, fluid balance adjustment, weaning CRRT); blood flow management using Doppler and continuous glomerular filtration rate (GFR) monitoring[34] are now becoming possible.

QUALITY

Quality outcome data for the practical application and delivery of CRRT are not defined clearly, with little evidence for the collection of any data being associated with improved patient outcomes. However, monitoring data associated with CRRT can be useful to improve efficacy or prevent adverse events and morbidity. Fluid balance adherence is a useful quality activity because positive fluid balance and fluid balance errors have been linked to longer ICU stay and increased morbidity.[35–38] Circuit use time before clotting is considered useful to know and is the primary measurement for assessing anticoagulation agents used during CRRT and/or adherence to the chosen method. However, this data may also be influenced by placement, use and troubleshooting the access device, CRRT machine operation and response to alarm events, or any additional clinical care event interrupting treatment or causing the treatment to stop unexpectedly.[39–42] In addition, outside ICU procedures, line changes, unexpected discharge from the ICU, or communication errors between prescribing physicians and nurses can create time off treatment. Therefore the prescribed versus delivered treatment within each 24 hour period is another secondary useful measurement, independent of filter or circuit life. It has been an important demographic variable for equivalence in large studies comparing dose[43,44] and increasing off time is associated with poor solute control.[11]

These measures of quality have been highlighted from a systematic review, appraising the evidence and quality protocol proposal inventory list to promote safe and efficient CRRT.[21] The broad aims of CRRT to control solutes, fluid balance, and acid base are additional simple variables to review and reflect the efficiency and quality of CRRT. The time from prescription to starting treatment may also reflect nursing efficiency as does the time lapse following a clotting event before a new treatment begins[21,41,45]: the circuit priming and machine preparation time. Nursing expertise for CRRT is related to frequency of use and the nursing model of care. Smaller ICU facilities with sporadic use of CRRT and no nursing link to a nephrology department will find it more difficult to maintain quality. Regular competency checks and staff assessments become more necessary. Continual experience with CRRT in larger hospitals and many AKI patients requiring CRRT every day provides the competency and quality process through familiarity, suggesting that checks are not necessary.[2,10,11,46]

MULTIDISCIPLINARY TEAM

The successful implementation of CRRT requires a group of people and includes all involved in the supply chain: clinical care (prescribing and use of CRRT), vendors, pharmacy, and biomedical technicians (Fig. 162.3). The team requires a smaller group within who are considered the "champions," and their role is to sustain the program and undertake quality and audit communication. The champions are represented best by nurses (e.g., manager, teacher, and clinician nurses). As with any program a team meeting and communications are vital to keep momentum and introduce changes or updates. Current email, smartphone apps, and/or notice board newsletters are some ideas. The team can be difficult to organize into a meeting time, but each person should have a substitute, or another who can act if he or she cannot. Because nursing attrition and turnover can be high in the ICU, succession planning is a key strategy.

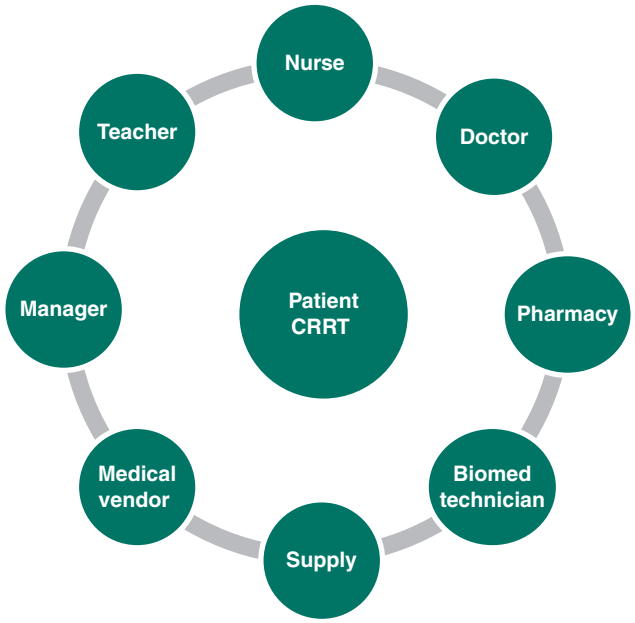


FIGURE 162.3 Schemata of stakeholders in continuous renal replacement therapy implementation.

Extracorporeal Membrane Oxygenation and Continuous Renal Replacement Therapy

Commonly ECMO is provided for patients with refractory hypoxemia in association with respiratory failure or in the presence of right heart failure and combined heart and lung failure.[47,48] These critically ill patients usually have AKI and require CRRT in addition to heart-lung support. It is convenient to connect the CRRT circuit to the ECMO circuit using the large-bore and high-flow cannulation used with ECMO. To avoid possible air entrainment to the ECMO membrane, it is safer to connect the CRRT line for outflow to the dialyzer post the ECMO pump and before the oxygenator membrane device.[47,48] A recent systematic review for the use of CRRT during ECMO highlighted these key clinical and technical considerations.[49] A limitation is high positive pressure at this position of the circuit and mandates CRRT machine alarms either be widened or switched to an ECMO setting or option allowing positive pressure readings where negative pressure is usual. Higher-dose anticoagulation provided for ECMO, usually as unfractionated heparin, is convenient for connecting in CRRT. Longer circuit life is likely with circuit changes being scheduled only when oxygenator changes occur after three or more days. Nurses manage the CRRT and ECMO either independently or in a shared responsibility with a perfusionist or an anesthetist usually responsible associated with cardiac bypass surgery or similar.

Continuous Renal Replacement Therapy in the Operating Room

Minimal experience is reported for use of CRRT in the OR. However, retrospective and small matched cohort studies during hepatic transplant reflect that CRRT in the OR is possible and can be performed with benefits for anesthesia and the management of AKI and can be provided safely.[50–52] One study found no differences in postoperative measures when CRRT was performed during hepatic transplant; however, the matched cohorts presented in the paper were sicker in the ICU before surgery, with AKI and higher Model for End-Stage Liver Disease (MELD) score presurgery compared with the control group.[52] For patients in the ICU with AKI and requiring this type of prolonged surgery, with an anhepatic period, CRRT continuity from the ICU and throughout the surgery would appear beneficial if this can be done. Local staffing patterns, and the surgical and anesthetic teams' working relationship with the ICU, will determine exactly how CRRT will be achieved in the OR. In one report the anesthesia team operated the CRRT independently of the ICU nurse.[52,53] Larger randomized trials may be useful in the setting of hepatic transplant. However, for patients with AKI in the ICU and those undergoing prolonged surgery, CRRT may be useful and nursing roles may respond into the OR accordingly.

ADVANCED THERAPY

Experience developed from CRRT can be used for advanced therapies in the ICU, such as plasma exchange (PE), combined plasma filtration and adsorption (CPFA), or membrane adsorbing recirculating system (MARS). Providing these treatments in the general ICU will require the skills of experienced CRRT users led by the champion group and with ICU physicians focused in this area of blood purification. Although CPFA and MARS are available, expensive and with limited controlled data reflecting outcome benefit, PE is more likely as there are some clear indications and benefits for some patient groups, and published apheresis guidelines reflect this.[54] This technique requires a plasma separator or specialized membrane used in the CRRT circuit and without a mode option, set as convective clearance hemofiltration is effective, but importantly, no fluid loss setting. Latest machines enable this treatment with settings or mode selection accordingly. This is plasma removal and plasma substitution, with no fluid loss set because the treatment is an equal exchange. The treatment usually is prescribed to complete after 4 to 6 hours or after 2.5 to 3.5 L of plasma is exchanged. In some cases further treatment with CRRT is continued around the PE.

CONCLUSION

The chapter has provided a brief review for several aspects of CRRT use in the ICU with a focus on the education and training pathway, machines for CRRT, policy and procedure documents, anticoagulation method, quality ideas, and the team approach with many disciplines involved led by a nurse as champion of CRRT in the ICU. Brief comments have been included for CRRT with ECMO and in the OR and for advanced therapies such as plasma exchange.

Key Points

1. Education and training pathways for continuous renal replacement therapy (CRRT) are key to a successful program.
2. Modern machines, policy and procedure documents, anticoagulation protocols, and standardized order sheets are key aspects for training and education.
3. A nurse as champion of CRRT in the intensive care unit is critical.

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