CHAPTER 177

Nomenclature: Techniques

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OBJECTIVES

This chapter will:

1. List the nomenclature related to extracorporeal renal replacement therapies.
2. Provide a detailed description of the main components and procedures of a treatment.
3. Define and characterize main extracorporeal therapies and techniques.

This chapter reports the conclusions of a consensus expert conference on the nomenclature of renal replacement therapy (RRT) techniques currently used to manage acute kidney injury (AKI) and other organ dysfunction syndromes in critically ill patients. A multidisciplinary approach was made to achieve harmonization of definitions, components, techniques, and operations of the extracorporeal therapies. This chapter describes the RRT techniques in detail with the relevant technology, procedures, and phases of treatment, and key aspects of volume management/fluid balance in critically ill patients. In addition, it describes recent developments in other extracorporeal therapies, including therapeutic plasma exchange, multiple organ support therapy, liver support, lung support, and blood purification in sepsis.

HARDWARE AND DEVICES

Continuous renal replacement therapy (CRRT) "hardware" includes the machine and all dedicated disposables. Knowledge of the nomenclature and the functions of the machine and its main components is extremely important, not only for nurses or technicians but also for clinicians.

Fig. 177.1 depicts a standard CRRT machine equipped with current technology.[1,2] Its main components include the following:

1. *Screen:* The monitor through which the user interacts with the machine
2. *Alarm light and sound indicators:* Visual and auditory alarms must be clear and comprehensive. The alarm settings should be categorized unequivocally according to a specific standard
3. *Inflow pressure (P_{IN}) sensor* (upstream of blood pump): Monitors the negative pressure in the blood inflow line between the patient's vascular access and the blood pump
4. *Blood pump:* Pump that controls the blood flow rate through the extracorporeal circuit
5. *Pre-blood pump:* Pump that controls the flow rate of solutions, mainly regional anticoagulants (e.g., citrate), into the blood inflow line before the blood pump

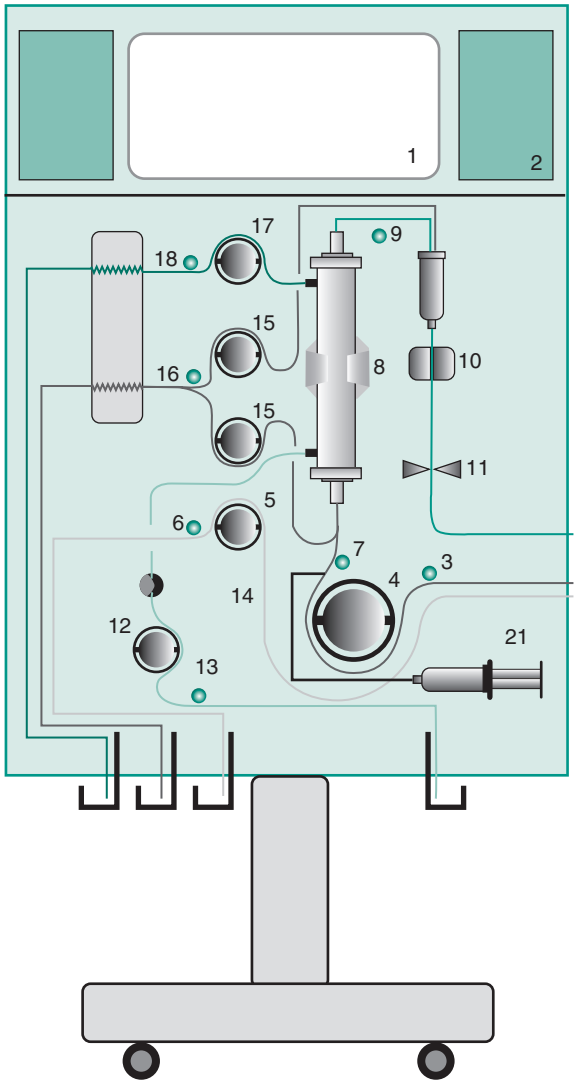

FIGURE 177.1 The CRRT machine (see text for explanation of numbered components). (Modified from Villa G, Neri M, Bellomo R, et al. Nomenclature for renal replacement therapy and blood purification techniques in critically ill patients: practical applications. *Crit Care.* 2016;20:283.)

6. *Preblood pump pressure sensor:* Monitors the pressure before the pre-blood pump
7. *Prefilter pressure (P_{PRE}) sensor* (downstream of blood pump): Located in the blood flow line between the blood pump and filter, this sensor monitors the positive pressure and enables calculation of the transmembrane pressure (TMP) and pressure drop (P_{DROP}) in the filter
8. *Filter holder:* Holds the filter or the entire filter-tubing kit on the machine

9. *Outflow pressure sensor (P_{OUT}):* Monitors the positive pressure between the filter and the patient vascular access. This sensor is used to calculate the TMP and pressure drop in the filter
10. *Bubble detector:* Transducer that detects the presence of air in the blood outflow line
11. *Safety outflow electroclamp:* Mechanism that produces occlusion of the blood outflow line
12. *Effluent/ultrafiltrate pump:* Pump that controls the rate of total fluid removal from the filter
13. *Effluent/ultrafiltrate pressure sensor (P_{EFF}):* Monitors the pressure in the effluent compartment of the filter. This sensor is placed before the effluent pump and allows calculation of the TMP
14. *Blood leak detector (BLD):* Placed along the effluent line, it identifies unwanted blood leaks from the blood compartment of the filter
15. *Replacement/infusion pump:* Pump that controls the rate of replacement fluid flow into the blood inflow line (predilution, usually between the blood pump and the filter) and/or into the blood outflow line (postdilution, usually in the blood outflow chamber, such as the deaeration or venous drip chamber)
16. *Prereplacement pump pressure sensor:* Monitors the negative pressure before the replacement pump
17. *Dialysate pump:* Pump that controls the rate of dialysate flow into the filter
18. *Predialysate pump pressure sensor:* Monitors the negative pressure before the dialysate pump
19. *Postdialysate pump pressure sensor (P_{Di}):* Monitors the pressure in the dialysate line before the connection with the filter. Permits a better estimate of TMP
20. *Fluid control system:* Allows direct monitoring of the fluid balance related to fluids exchanged by the CRRT machine during the treatment. It can be gravimetric, volumetric, fluximetric, or a combination of these mechanisms (see later in this chapter)
21. *Heater:* Heats the dialysate/replacement fluids, or the blood flowing through the blood outflow line of the extracorporeal circuit
22. *Anticoagulant/specific antagonist pumps:* Infuses anticoagulants/specific antagonists into the blood circuit. Depending on the anticoagulation modality chosen, these pumps can be divided further into systemic anticoagulation pumps (e.g., heparin), regional anticoagulation pumps (e.g., citrate) and reversal anticoagulation pumps (e.g., calcium). If necessary, specific antagonist drugs (e.g., protamine) can be infused via a separate pump (i.e., not integrated into the CRRT machine) into the blood outflow line

CONTINUOUS RENAL REPLACEMENT MACHINE: PROCEDURES AND PHASES OF TREATMENT

The different procedures performed by the machine[4] include the following:

Prescription phase: Decisions by the prescribing clinician about the required modality and related operational parameters and includes periodic reassessment and/or change of the prescription

Preparation phase: Collection of necessary disposable material, identification and checking of the disposable set, set loading (cassette tubing), connection to the filter, positioning of the tubing, and hanging of bags

Priming phase: Priming solution is infused into the extracorporeal circuit to remove air and impurities remaining after sterilization of the set. When heparin anticoagulation is used, it usually is added to the priming solution. During this phase, the machine makes a general check of all components and sensors

Connection to the patient: Connection of the extracorporeal lines to the patient's vascular access

Treatment phase: Net ultrafiltration and diffusive and/or convective solute transport are activated (all the pumps are working) and blood purification is performed. Patient vital signs and circuit pressures must be monitored throughout the treatment phase

Special procedures: During treatment, special procedures can include replenishment of dialysate, replacement fluid, citrate bags (when citrate anticoagulation is used) and change of syringes (when using heparin anticoagulation), repositioning of the vascular access, temporary disconnection, recirculation, and replacement of filter and kit

Blood return, disconnection, and unload: Blood return procedure returns the blood to the patient. This usually is done by connecting a saline solution bag to the inflow blood line and running the blood pump. When the circuit is flushed, the blood pump is stopped, the blood outflow line disconnected, and the tubing and filter unloaded

CONTINUOUS RENAL REPLACEMENT THRAPY DISPOSABLES

Disposables (single-use components of the extracorporeal circuit) are specific for every machine and usually are designed for a specific treatment modality. The main disposables[5] and color codes that should mark each tubing line are listed in Table 177.1.

During CRRT, the filter is the key disposable through which blood or plasma is purified effectively by ultrafiltration, convection, and/or diffusion. Historically, the designation "filter" describes the entire purifying extracorporeal device system (i.e., membranes, housing). Among the different types of filters, hemofilters, hemodialyzers, and hemodiafilters should be used when exclusively convective, diffusive, or convective plus diffusive modalities, respectively, are applied. In this manuscript we use these terms distinctly, taking into account the different CRRT modalities. A plasmafilter is defined as a specific filter that allows the separation of plasma from cellular elements. Sorbents, cartridges, and adsorbers do not belong to the category of filters; in this case, adsorption is the only purifying modality. The only available type of CRRT filter that can perform diffusive and/or convective transport is shaped as a collection of parallel "hollow fibers." The filters can be identified mainly by membrane geometrics and performance characteristics.[7–9]

VOLUME MANAGEMENT AND FLUID BALANCE

Fluid management during CRRT must take into account the volume and hemodynamic status of the patient. The machine fluid balance error (FBE) is the fluid management error caused by CRRT machine malfunction. Based on the

TABLE 177.1

Main Disposables and Their Components With Associated Color Code in a Continuous Renal Replacement Therapy Extracorporeal Circuit

Tubes	
Blood inflow line	Segment connecting the patient's vascular access to the filter
(red)	Segment for pressure measure (upstream blood pump):
Previously known as access	Segment of the blood inflow line connected to the inflow pressure sensor
or arterial line	Pump segment line: segment inserted between the rotor and the stator of the blood pump
	Blood inflow air removal chamber: allows removal of light air bubbles before the blood enters the filter
	Segment for pressure measure (downstream blood pump): segment of the blood inflow line connected to the prefilter pressure sensor
Blood outflow line	Segment connecting the filter to the patient's vascular access
(dark blue)	Segment for pressure measurement: segment of the blood outflow line connected to the outflow pressure sensor
Previously known as return	Blood outflow air removal chamber: allows removal of light air bubbles before the blood returns to the patient
or venous line	
Effluent/ultrafiltrate line	Segment that allows the flow of waste fluids from the filter
(yellow)	Pump segment line: segment inserted between the rotor and the stator of the effluent/ultrafiltrate pump
	Segment for pressure measure: segment of the effluent line connected to the effluent/ultrafiltrate pressure sensor
Dialysate line	Segment that allows the flow of incoming dialysate into the filter
(green)	Pump segment line: segment inserted between the rotor and the stator of the dialysate pump
	Segment for pressure measurement (if present): segment of the dialysate line connected to the dialysate pressure sensor
	Heater line: segment of the dialysate line placed in contact with the heater
Replacement line	Segment that allows the flow of replacement fluid into the blood inflow and/or blood outflow lines
(purple or light blue)	Pump segment line: segment inserted between the rotor and the stator of the replacement pump
	Segment for pressure measurement (if present): segment of the replacement line connected to the replacement pressure sensor
	Heater line: segment of the replacement line placed in contact with the heater
Pre-blood line	Segment that allows the flow of specific fluids (mainly regional anticoagulants) into the blood inflow line before the blood pump
(orange)	Pump segment line: segment inserted between the rotor and the stator of the pre-blood pump
	Segment for pressure measurement (if present): segment of the pre-blood line connected to the preblood pressure sensor
Anticoagulant and specific	Segments connecting the anticoagulant/specific antagonist bag or pump to the main blood circuit
antagonists line	Citrate line *(orange)*: segment for citrate infusion (i.e., pre-blood line)
	Heparin line *(white)*: segment connecting the heparin syringe pump to the blood inflow line
	Specific antagonist line *(gray)*: segment connecting the specific antagonist syringe pump to the blood outflow line
Filter	
Fiber (membranes)	Every fiber, hollow and of cylindric shape, allows the fluids and solutes transport phenomena through their porous semipermeable surface
Bundle	Entire number of fibers inside the housing
Housing	Plastic casing containing a single membrane fiber bundle
	Blood inflow port: entrance port of blood entering into the filter
	Blood outflow port: exit port of blood outing from the filter
	Dialysate inflow port: entrance port of fresh dialysate
	Effluent/ultrafiltrate outflow port: exit port of waste solution
Potting	Polyurethane component fixing the bundle within the housing and embedding the bundle at both ends of the filter

Modified from Neri M, Cerda J, Garzotto F, et al. Nomenclature for Renal Replacement Therapy in Acute Kidney Injury. In: *Continuous Renal Replacement Therapy.* New York: Oxford University Press; 2016.

inherent variability ("tolerances") in the performance of the fluid pumps, scales, and other components of a CRRT machine's fluid management system, the manufacturer provides a specified limit ("specification") beyond which a fluid imbalance is considered an error. Fluid imbalances can be due to hardware (scales, pumps, tubes) or software (control system and protective subsystem) errors.

Various systems have been proposed for fluid balancing in CRRT machines:

- Gravimetric fluid balancing, using one or more scales, is used most commonly in CRRT because it is the most reliable technique during long treatment intervals. A fundamental aspect of this type of system is the continuous weighing of the effluent along with replacement fluid and/or dialysate, with weight acting as a surrogate for fluid flow rate. The machine software analyzes these scale data on an ongoing basis, and any discrepancies between prescribed and actual values lead to adjustments in pump rates based on a servo-feedback mechanism. Disadvantages include limitations in scale capacity, user errors, and other disturbances of the operating environment.
- In volumetric fluid balancing, a system of balancing chambers and valves is used. During long treatments, volumetric balancing is less accurate than gravimetric balancing because of systematic, cumulative errors, because there is no continuous servo-feedback safeguard

for this approach. The advantage of this system is that it eliminates the need to collect effluent and thus reduces the frequency of fluid-related interventions.
- Fluxometric fluid balancing requires the application of accurate but expensive flowmeters (electromagnetic, ultrasonic and Coriolis flowmeters).

All these methods can be applied individually or in combination.

EXTRACORPOREAL THERAPIES AND TREATMENTS

Extracorporeal therapies can be categorized according to session frequency and duration.

Continuous Therapies

CRRT is any extracorporeal technique that replaces kidney function and more generally provides blood purification for an extended period of time. CRRT is considered by many clinicians to be the most appropriate modality for the management of hemodynamically unstable patients with AKI, promoting better hemodynamic stability, reduced transcellular solute shifts, and better tolerance to fluid removal than intermittent extracorporeal therapies. The need for expertise, the necessity of continuous anticoagulation, the nursing workload, the continuous alarm vigilance, and the higher costs are some of the limitations of this approach. CRRT can be provided in various forms depending on resources, patient needs, and staff skills[10–12] (Fig. 177.2).

Prescription should be reviewed regularly.

CRRT treatments currently are performed using a double-lumen catheter as vascular access, a venovenous technique, whereby blood is driven from a vein and, after being purified, returns to the same vein. Arteriovenous circuits have been virtually abandoned.

Slow Continuous Ultrafiltration

Slow continuous ultrafiltration (SCUF), based only on slow removal of plasma water, is used for patients with refractory fluid overload, with or without renal dysfunction. Its primary aim is to achieve safe and effective correction of fluid overload.

Continuous Venovenous Hemofiltration

Continuous venovenous hemofiltration (CVVH) uses convection, with ultrafiltrate replaced in part or completely with appropriate replacement fluids, to achieve solute clearance and volume control. Replacement fluid can be infused before (predilution) and/or after (postdilution) the hemofilter.

Continuous Venovenous Hemodialysis

Continuous venovenous hemodialysis (CVVHD) is a form of continuous hemodialysis characterized by countercurrent/co-current dialysate flow rate into the dialysate compartment of the hemodialyzer. The main mechanism of transmembrane solute transport is diffusion.

Continuous Venovenous Hemodiafiltration

Continuous venovenous hemodiafiltration (CVVHDF) combines hemodialysis and hemofiltration modalities. Ultrafiltrate is replaced in part or completely by replacement

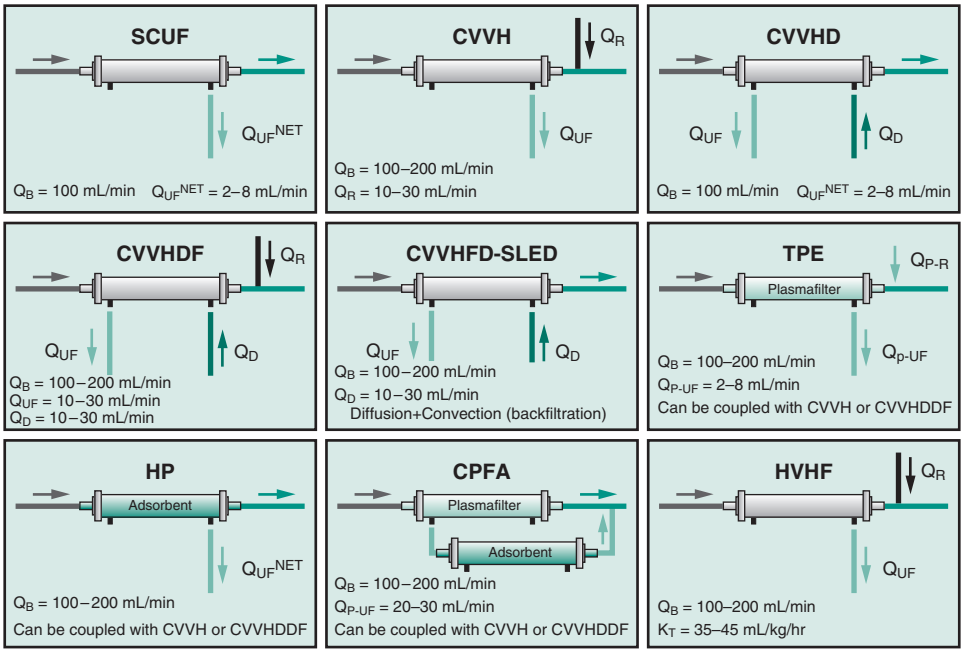

FIGURE 177.2 Main extracorporeal therapies and treatments. Q_B, Blood flow rate; Q_D, dialysate flow rate; Q_{EFF}, effluent flow rate; $Q_{P\text{-}R}$, replacement plasma flow rate; $Q_{P\text{-}UF}$, Plasma ultrafiltration flow rate; Q_R, total replacement flow rate; Q_{UF}, ultrafiltration flow rate; Q_{UF}^{NET}, net ultrafiltration flow rate. (Modified from Cerda J, Ronco C. Modalities of continuous renal replacement therapy: technical and clinical considerations. *Semin Dialysis*. 2009;22:114–122.)

fluid (pre- or postinfusion) and countercurrent/co-current dialysate flow into the dialysate compartment. Solute clearance is achieved via diffusive and convective clearance.

Continuous Venovenous High-Flux Hemodialysis

Continuous venovenous high-flux hemodialysis (CVVHFD) consists of the same treatment as in CVVHD but is carried out using high-flux membranes. Because of the high-flux properties of the membrane, a convective component of solute clearance is achieved even if replacement fluid is not infused.

Intermittent Therapies

Intermittent therapies are carried out in sessions of 3 to 5 hours. They require adequate vascular access, specially trained nurses, and water processing and sterilization that produces pure water for dialysate. Because treatment times are relatively short, the depuration rate must be higher than that of CRRT. The most commonly prescribed intermittent therapies are intermittent hemodialysis (IHD), intermittent hemofiltration (IHF), intermittent hemodiafiltration (IHDF), and intermittent high-flux dialysis (IHFD). Other therapies are available combining different modalities, but these usually are not performed in the intensive care unit (ICU), so are not discussed here.

Hybrid Therapies

With respect to frequency and duration, the term *hybrid therapies* relates to the blending of characteristics from intermittent and continuous modalities. These therapies attempt to optimize the advantages and minimize the disadvantages of both modalities: efficient solute removal, slower ultrafiltration rates for hemodynamic stability, less anticoagulant exposure, shorter duration, lower costs, decreased nurse workload, and improved ICU workflow. Hybrid therapies encompass various specific "discontinuous" RRT modalities: sustained low-efficiency dialysis (SLED), slow low-efficiency extended daily dialysis (SLEDD), prolonged intermittent RRT (PIRRT), extended daily dialysis (EDD), extended daily dialysis with filtration (EDDf), extended dialysis (ED), "go slow dialysis," and accelerated venovenous hemofiltration (AVVH). Hybrid therapies usually are performed with standard intermittent hemodialysis equipment, including machines, filters, extracorporeal blood circuits, and, in some cases, online fluid production for dialysate and ultrafiltrate infusion. Solute removal is largely diffusive, but variants with a convective component, such as EDD-f and AVVH, are possible.

The most commonly prescribed hybrid therapy is SLED, a technique that uses reduced blood and dialysate flow rates and usually is limited to 8 to 12 hours. There are limited data from appropriately powered studies on the application of these techniques.[13]

Other Extracorporeal Therapies

Other blood purification techniques also are performed in the ICU to clear toxins and solutes generally not removable by "classic" RRT, or to support single or multiple organ dysfunction. Although the delivery of CRRT may be achieved without anticoagulation in some patients, these therapies typically require some form of anticoagulation.

Therapeutic Plasma Exchange

Therapeutic plasma exchange (TPE) consists of the automated removal of plasma (plasmapheresis) and its replacement (exchange) with a suitable fluid composed of fresh frozen plasma or albumin.

TPE is performed using a centrifugal-based system or a very highly permeable membrane that allows separation of plasma from the cellular elements of blood. In membrane-based TPE, pore sizes ranging between 0.2 and 0.6 microns allow a sieving coefficient (SC) of 0.9 to 1.0 for molecules with a molecular weight greater than 500 KDa.[14] Continuous plasma exchange (CPE) is a therapy derived from TPE that is performed with lower flow rates and for a longer period of time. Single or repeated sessions can be performed as pure CPE or in conjunction with other purification techniques.

Multiple Organ Support Therapy

Recently, CRRT has been used in a wide range of nonrenal applications, including multi-organ support therapies (MOST), to manage patients with multi-organ dysfunction syndrome.[15] MOST requires a complex extracorporeal support system with a multitasking machine platform and multiple devices. The type and intensity of organ support therapy can be modulated according to the number and severity of organ dysfunctions.

HEART SUPPORT. In myocardial dysfunction, right and left ventricular dysfunction can be complicated by severe fluid overload.[16] SCUF, performed in patients with or without AKI, can reduce fluid overload, improve cardiac filling volumes and contractility, and usually is well tolerated among hemodynamically unstable cardiac failure patients.[17] It may be especially worthy of consideration in patients with severe diuretic resistance and cardiorenal syndrome, for whom therapeutic options are limited.

LIVER SUPPORT. Artificial liver support includes cell-based and non–cell-based devices, including conventional IHD, CRRT, and devices specifically designed to clear accumulated toxins associated with liver dysfunction.[18,19] In many non–cell-based systems, an albumin-enriched dialysate is necessary to remove such toxins (e.g., fatty acids, hydrophobic bile acids, and nitric oxide), which are highly albumin bound. This "albumin dialysis" concept forms the basis of single-pass albumin dialysis (SPAD) and the molecular adsorbent recirculating system (MARS), whereas Prometheus (Fresenius Medical Care, Bad Homburg, Germany) is based on fractionated plasma separation and adsorption (FPSA).[20]

1. Single-pass albumin dialysis
   In SPAD, albumin is used as a component of the dialysate for more effective protein-bound toxin removal. The blood is placed in contact with a standard albumin-impermeable high-flux membrane and is dialyzed against an albumin-containing dialysate. Protein-bound molecules that are small enough to pass from the blood compartment through the membrane pores are dialyzed and then bound to albumin in the dialysate. SPAD provides a single pass of fresh albumin dialysate; this characteristic constitutes the major difference between SPAD and MARS.[21,22]
2. Molecular adsorbent recirculating system
   MARS uses a hemodialyzer in a primary circuit, which is connected to a secondary circuit composed of a standard hemodialyzer, an activated carbon adsorber, and an anion exchanger. In the primary circuit, the

patient's blood is pumped into the MARS hemodialyzer and water-soluble substances diffuse through the dialysate solution. This membrane has a size selection threshold of less than 60 kDa, thus retaining albumin on the blood side; only the free fraction of toxins can cross the membrane in a manner similar to SPAD. The dialysate compartment of the MARS hemodialyzer is part of a secondary circuit, where a 20% albumin solution circulates in a countercurrent flow. Toxins can bind to the free albumin in the secondary circuit, whereas clearance of water-soluble substances occurs in a standard CRRT hemodialyzer. Hydrophobic albumin-bound toxins then are extracted by passage through activated charcoal and anion exchange columns, thus regenerating the albumin binding sites. The reconstituted albumin then is recirculated to maintain a transmembrane concentration gradient in the primary circuit hemodialyzer.

3. Prometheus FPSA
   The Prometheus system is based on FPSA combined with hemodialysis. The patient's blood is pumped toward a specific albumin-permeable membrane with a size-selection threshold of 250 kDa. The albumin fraction of blood is filtered selectively, and albumin-bound toxins can pass the membrane freely by convection. In a secondary circuit, the filtered albumin-rich plasma fraction is treated by two absorber columns: a neutral resin absorber and an anion exchanger for removal of negatively charged toxins. The purified albumin-rich plasma fraction is reinfused into the primary circuit where, in a second step, conventional hemodialysis is performed to eliminate water-soluble molecules.[23,24]

LUNG SUPPORT. There is well-established evidence of interaction between lung and kidney functions, and many critically ill patients may require concomitant extracorporeal kidney and lung support.[25,26] In most cases, CRRT can be performed with the same vascular access used for extracorporeal lung support therapies, for therapies requiring high blood flows (extracorporeal membrane oxygenation [ECMO][27]) and, more recently, for therapies requiring low blood flows. ECMO frequently is performed in conjunction with CRRT, and different circuit configurations can be used.[25] Conventional ECMO systems typically require blood flow rates substantially higher than those used in CRRT, although new therapies using lower blood flows may be sufficient even to achieve adequate extracorporeal oxygenation.[28] On the other hand, new lung support modalities using blood flow rates similar to those applied in CRRT (and capable of being provided by CRRT machines) are sufficient to perform extracorporeal CO_2 removal.[29]

BLOOD PURIFICATION IN SEPSIS. In patients with hyperinflammation (mainly during sepsis), extracorporeal blood purification therapies have the potential to modulate the host inflammatory response through the removal of inflammatory mediators and/or bacterial toxins.

1. High-volume hemofiltration (HVHF)
   Although not unequivocally defined in the medical literature, HVHF (see Fig. 177.2) is identified as continuous treatment with a convective target dose (prescribed) greater than 35 mL/kg/hr.[30,31] Continuous treatments with a dose greater than 45 mL/kg/hr identify very high-volume hemofiltration (VHVHF) modalities. Intermittent procedures with brief, very high-volume treatments at 100 to 120 mL/kg/hr for 4 to 8 hours, followed by conventional CVVH, are identified as pulse high-volume hemofiltration (pulse HVHF).[32]
   However, there is no evidence that HVHF, when compared with standard dose hemofiltration, leads to a reduction in mortality.[33] There is insufficient evidence to routinely recommend the use of HVHF in critically ill patients with severe sepsis and/or septic shock except as interventions being investigated in the setting of a randomized clinical trial.
2. Continuous plasma filtration coupled with adsorption
   Continuous plasma filtration coupled with adsorption (CPFA) is a blood purification therapy (see Fig. 177.2) that combines the advantages of CRRT and continuous plasma filtration without requiring large amount of plasma substitutes. In the first step of CPFA, a plasma filter separates plasma from blood cellular component, and the plasma filtrate is pumped through a sorbent. The purified plasma then is returned to the main circuit, where blood is reconstituted and treated with standard CRRT modalities. There is no evidence that CPFA reduces mortality in patients with septic shock or that it positively affects other important clinical outcomes.[34]
3. Hemoperfusion
   Continuous hemoperfusion involves placement of a sorbent cartridge in series with the filter (see Fig. 177.2) to remove those toxins that are not removable by classic CRRT. The sorbent is placed in direct contact with blood and adsorbs solutes through hydrophobic interactions, ionic attraction, hydrogen bonds, and van der Waals interactions.[35] Hemoperfusion requires an extremely biocompatible sorbent coated with a surface that prevents platelet adhesion and clotting activation. The removal characteristics of hemoperfusion are dependent on the different types of sorbent used, with effective surface area playing an important role.
   Polymyxin (PMX)-hemoperfusion is a technique based on the use of a cartridge containing fibers coated with PMX-B, an antibiotic with high affinity for lipopolysaccharide. The aim is to remove circulating endotoxin. There have been controversial results from studies of PMX-hemoperfusion. Nevertheless, the most recent results seem to suggest no improvement in organ failure in patients treated with PMX-hemoperfusion.[36,37]

CONCLUSION

Application of technology at the bedside requires full knowledge of the basic principles and the operating mechanisms for every technique. When faced with a patient with complex healthcare needs, practitioners can use a growing variety of extracorporeal treatment options. Although definitive evidence is still lacking in many areas, there is general consensus that the degree of hemodynamic stability is the main determinant of the choice of RRT modality,[11] as shown in two large studies on the appropriate dose of dialysis.[38–40] Understanding the importance of dose quantification and ensuring the delivery of an adequate dose appear to be critical determinants of patient outcome. Although preliminary evidence suggests that timely initiation of RRT is important,[41,42] definitive studies to answer that question are currently in progress. For patients with multiple organ failure, an increasing panoply of options is being developed, including extracorporeal treatments for sepsis, and for cardiac, pulmonary, and liver failure.

In this complex scenario, a multidisciplinary clinical care team composed of specialists from different disciplines

and highly trained nurses is crucial to the success of the treatment. We provide a framework for harmonization of terminology to reduce the errors and complications that can result from poor understanding and inadequate delivery of the prescribed therapies. Homogenized nomenclature is also important when reporting machine functions and clinical parameters to enable study comparisons and advance our understanding in this field, ultimately allowing for improvements in clinical practice and patient outcomes.

We trust that new publications, electronic medical records, and machine software will be designed and operated in compliance with the agreed terminology to enable consistent data collection and comparison.

LIST OF ABBREVIATIONS

AKI	Acute kidney injury
AVVH	Accelerated venovenous hemofiltration
BLD	Blood leak detector
CPE	Continuous plasma exchange
CPFA	Continuous plasmafiltration coupled with adsorption
CVVH	Continuous venovenous hemofiltration
CVVHD	Continuous venovenous hemodialysis
CVVHDF	Continuous venovenous hemodiafiltration
CVVHFD	Continuous venovenous high-flux dialysis
CRRT	Continuous renal replacement therapy
ECMO	Extracorporeal membrane oxygenation
ED	Extended dialysis
EDD	Extended daily dialysis
EDDf	Extended daily dialysis with filtration
FBE	Fluid balance error
FPSA	Fractionated plasma separation and adsorption
HVHF	High-volume hemofiltration
ICU	Intensive care unit
IHD	Intermittent hemodialysis
IHDF	Intermittent hemodiafiltration
IHF	Intermittent hemofiltration
IHFD	Intermittent high-flux dialysis
MARS	Molecular adsorbent recirculating system
MOST	Multiple organ support therapy
PIDRRT	Prolonged intermittent daily renal replacement therapy
PMX	Polymyxin
P_{DROP}	Pressure drop
P_{EFF}	Pressure in the effluent line
P_{IN}	Inflow pressure
P_{OUT}	Outflow pressure
P_{PRE}	Prefilter pressure
Q_B	Blood flow rate
Q_D	Dialysate flow rate
Q_{EFF}	Effluent flow rate
Q_P	Plasma flow rate
$Q_{P\text{-}R}$	Replacement plasma flow rate
$Q_{P\text{-}UF}$	Plasma ultrafiltration flow rate
Q_R	Total replacement flow rate
Q_R^{POST}	Replacement flow rate postfilter
Q_R^{PRE}	Replacement flow rate prefilter
Q_{UF}	Ultrafiltration flow rate
Q_{UF}^{NET}	Net ultrafiltration flow rate
RRT	Renal replacement therapy
SC	Sieving coefficient
SCUF	Slow continuous ultrafiltration
SLED	Sustained low-efficiency dialysis
SLEDD	Slow low-efficiency extended daily dialysis
SPAD	Single-pass albumin dialysis
TMP	Transmembrane pressure
TPE	Therapeutic plasma exchange
VHVHF	Very high-volume hemofiltration

Key Points

1. Standardized definitions regarding machines performing continuous renal replacement therapies are important to avoid describing the same concept with different names.
2. Machine components, disposable devices, and operations involved in renal replacement therapies should be known and used appropriately by all the professional figures (clinicians, nurses, technicians) who are at the bedside of the patient to allow fast communication and immediate comprehension.
3. The harmonization of terminology in extracorporeal renal replacement therapies will help to reduce errors and complications that can result from poor understanding and inadequate delivery of the prescribed therapies.

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