Supportive Therapies: Intermittent Hemodialysis, Continuous Renal Replacement Therapies, and Peritoneal Dialysis

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Over the last decade, significant advances have been made in the availability of different dialysis methods for replacement of renal function. Although the majority of these have been developed for patients with end-stage renal disease, more and more they are being applied for the treatment of acute renal failure (ARF). The treatment of ARF, with renal replacement therapy (RRT), has the following goals: 1) to maintain fluid and electrolyte, acid-base, and solute homeostasis; 2) to prevent further insults to the kidney; 3) to promote healing and renal recovery; and 4) to permit other support measures such as nutrition to proceed without limitation. Ideally, therapeutic interventions should be designed to achieve these goals, taking into consideration the clinical course. Some of the issues that need consideration are the choice of dialysis modality, the indications for and timing of dialysis intervention, and the effect of dialysis on outcomes from ARF. This chapter outlines current concepts in the use of dialysis techniques for ARF.

CHAPTER

19

Dialysis Methods

DIALYSIS MODALITIES FOR ACUTE RENAL FAILURE

Intermittent therapies	Continuous therapies
Hemodialysis (HD)	Peritoneal (CAPD, CCPD)
Single-pass	Ultrafiltration (SCUF)
Sorbent-based	Hemofiltration (CAVH, CVVH)
Peritoneal (IPD)	Hemodialysis (CAVHD, CVVHD)
Hemofiltration (IHF)	Hemodiafiltration (CAVHDF, CVVHDF) CVVHDF
Ultrafiltration (UF)	

FIGURE 19-1

Several methods of dialysis are available for renal replacement therapy. While most of these have been adapted from dialysis procedures developed for end-stage renal disease several variations are available specifically for ARF patients [1] .

Of the intermittent procedures, intermittent hemodialysis (IHD) is currently the standard form of therapy worldwide for treatment of ARF in both intensive care unit (ICU) and non-ICU settings. The vast majority of IHD is performed using single-pass systems with moderate blood flow rates (200 to 250 mL/min) and countercurrent dialysate flow rates of 500 mL/min. Although this method is very efficient, it is also associated with hemodynamic instability resulting from the large shifts of solutes and fluid over a short time. Sorbent system IHD that regenerates small volumes of dialysate with an in-line Sorbent cartridge have not been very popular; however, they are a useful adjunct if large amounts of water are not available or in disasters [2]. These systems depend on a sorbent cartridge with multiple layers of different chemicals to regenerate the dialysate. In addition to the advantage of needing a small amount of water (6 L for a typical run) that does not need to be pretreated, the unique characteristics of the regeneration process allow greater flexibility in custom tailoring the dialysate. In contrast to IHD, intermittent hemodiafiltration (IHF), which uses convective clearance for solute removal, has not been used extensively in the United States, mainly because of the high cost of the sterile replacement fluid [3]. Several modifications have been made in this therapy, including the provision of on-line preparation of sterile replacement solutions. Proponents of this modality claim a greater degree of hemodynamic stability and improved middle molecule clearance, which may have an impact on outcomes.

As a more continuous technique, peritoneal dialysis (PD) is an alternative for some patients. In ARF patients two forms of PD have been used. Most commonly, dialysate is infused and drained from the peritoneal cavity by gravity. More commonly a variation of the procedure for continuous ambulatory PD termed continuous equilibrated PD is utilized [4]. Dialysate is instilled and drained manually and continuously every 3 to six hours, and fluid removal is achieved by varying the concentration of dextrose in the solutions. Alternatively, the process can be automated with a cycling device programmed to deliver a predetermined volume of dialysate and drain the peritoneal cavity at fixed intervals. The cycler makes the process less labor intensive, but the utility of PD in treating ARF in the ICU is limited because of: 1) its impact on respiratory status owing to interference with diaphragmatic excursion; 2) technical difficulty of using it in patients with abdominal sepsis or after abdominal surgery; 3) relative inefficiency in removing waste products in "catabolic" patients; and 4) a high incidence of associated peritonitis. Several continuous renal replacement therapies (CRRT) have evolved that differ only in the access utilized (arteriovenous [nonpumped: SCUF, CAVH, CAVHD, CAVHDF] versus venovenous [pumped: CVVH, CVVHD, CVVHDF]), and, in the principal method of solute clearance (convection alone [UF and H], diffusion alone [hemodialyis (HD)], and combined convection and diffusion [hemodiafiltration (HDF)]).

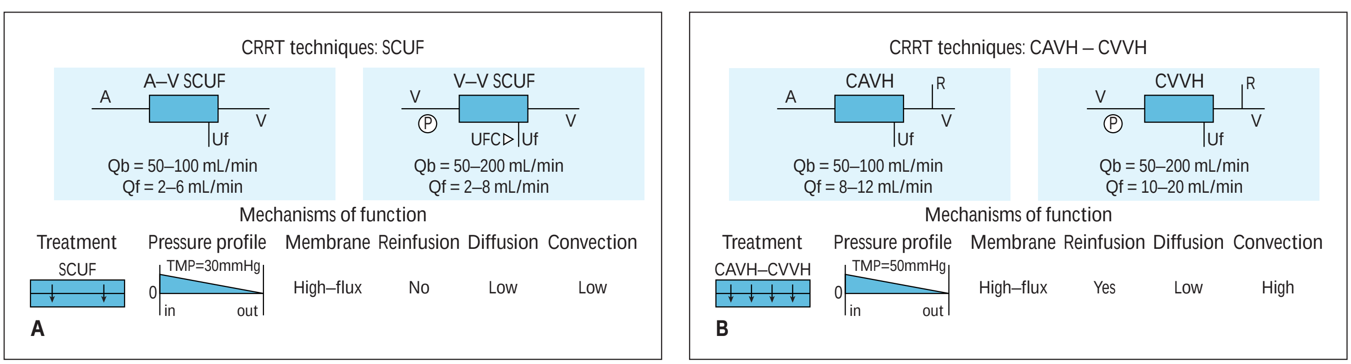

FIGURE 19-2

Schematics of different CRRT techniques. **A**, Schematic representation of SCUF therapy. **B**, Schematic representation of continuous arteriovenous or venovenous hemofiltration (CAVH/CVVH) therapy.

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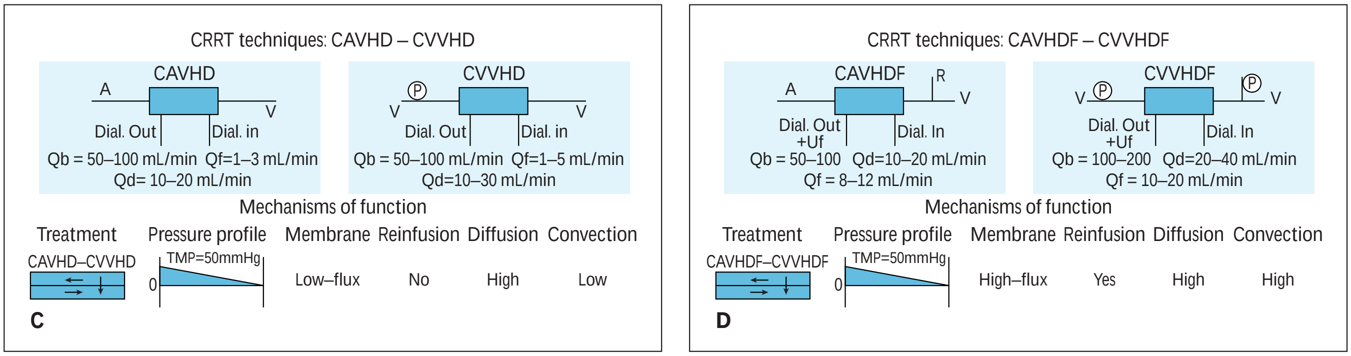

FIGURE 19-2 *(Continued)*

C, Schematic representation of continuous arteriovenous/venovenous hemodialysis (CAVHD-CVVHD) therapy. **D**, Schematic representation of continuous arteriovenous/venovenous hemodiafiltration (CAVHDF/CVVHDF) therapy. A—artery; V—vein; Uf—ultrafiltrate; R—replacement fluid; P—peristaltic pump; Qb—blood flow; Qf—ultrafiltration rate; TMP—transmembrane pressure; in—dilyzer inlet; out—dialyzer outlet; UFC—ultrafiltration control system; Dial—dialysate; Qd—dialysate flow rate. (*From* Bellomo *et al.* [5]; with permission.)

CONTINUOUS RENAL REPLACEMENT THERAPY: COMPARISON OF TECHNIQUES

	SCUF	CAVH	CVVH	CAVHD	CAVHDF	CVVHD	CVVHDF	PD
Access	AV	AV	VV	AV	AV	VV	VV	Perit. Cath.
Pump	No	No	Yes	No	No	Yes	Yes	No†
Filtrate (mL/h)	100	600	1000	300	600	300	800	100
Filtrate (L/d)	2.4	14.4	24	7.2	14.4	7.2	19.2	2.4
Dialysate flow (L/h)	0	0	0	1.0	1.0	1.0	1.0	0.4
Replacement fluid (L/d)	0	12	21.6	4.8	12	4.8	16.8	0
Urea clearance (mL/min)	1.7	10	16.7	21.7	26.7	21.7	30	8.5
Simplicity*	1	2	3	2	2	3	3	2
Cost*	1	2	4	3	3	4	4	3

* 1 = most simple and least expensive; 4 = most difficult and expensive
† cycler can be used to automate exchanges, but they add to the cost and complexity

FIGURE 19-3

In contrast to intermittent techniques, until recently, the terminology for continuous renal replacement therapy (CRRT) techniques has been subject to individual interpretation. Recognizing this lack of standardization an international group of experts have proposed standardized terms for these therapies [5]. The basic premise in the development of these terms is to link the nomenclature to the operational characteristics of the different techniques. In general all these techniques use highly permeable synthetic membranes and differ in the driving force for solute removal. When arteriovenous (AV) circuits are used, the mean arterial pressure provides the pumping mechanism. Alternatively, external pumps generally utilize a venovenous (VV) circuit and permit better control of blood flow rates. The letters AV or VV in the terminology serve to identify the driving force in the technique. Solute removal in these techniques is achieved by convection, diffusion, or a combination of these two. Convective techniques include ultrafiltration (UF) and hemofiltration (H) and depend on solute removal by solvent drag [6]. Diffusion-based techniques similar to intermittent hemodialysis (HD) are based on the principle of a solute gradient between the blood and the dialysate. If both diffusion and convection are used in the same technique the process is termed hemodiafiltration (HDF). In this instance, both dialysate and a replacement solution are used, and small and middle molecules can both be removed easily. The letters UF, H, HD, and HDF identify the operational characteristics in the terminology. Based on these principles, the terminology for these techniques is easier to understand. As shown in Figure 19-1 the letter C in all the terms describes the continuous nature of the methods, the next two letters [AV or VV] depict the driving force and the remaining letters [UF, H, HD, HDF] represent the operational characteristics. The only exception to this is the acronym SCUF (slow continuous ultrafiltration), which remains as a reminder of the initiation of these therapies as simple techniques harnessing the power of AV circuits. (*Modified from* Mehta [7]; with permission.)