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Workbook on Renal Replacement Therapy in ICU



Valentine Lobo
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Foreword
Shirish Prayag

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CONTENTS

1. **Acute Kidney Injury: Definition, Classification, Diagnostic Strategies, and Prevention** 1
   Kayanoosh J Kadapatti

2. **Biomarkers in Acute Kidney Injury** 11
   Siddhesh Dhaygude

3. **Principles of Renal Replacement Therapy in Critical Care** 20
   Valentine Lobo

4. **Renal Replacement Therapy: Nomenclature and Terminology** 27
   Sachin S Soni, Shriganesh R Barnela, Sonali S Saboo, Unmesh V Takalkar, Suresh H Saboo

5. **Indications and Timing of RRT in AKI** 35
   Sunitha Binu Varghese

6. **Vascular Access for Renal Replacement Therapy** 45
   Tarun K Jeloka

7. **Choosing Dialyzers and Hemofilters** 52
   Snehal Gaikwad

8. **Set Up and Prescription for CRRT** 63
   Ranajit Chatterjee, Ashutosh Garg, Juliet Merlene

9. **Set Up and Prescription for Sustained Low-efficiency Dialysis** 75
   Sunil Karanth

10. **Anticoagulation on RRT** 81
    Pradeep D'costa

11. **Acute Peritoneal Dialysis in Critical Care** 89
    Vipul Chakurkar

12. **Complications and Monitoring of Renal Replacement Therapy in Acute Kidney Injury** 98
    Rajeev A Annigeri

13. **Chronic Kidney Disease Patient in ICU** 108
    Tarun K Jeloka

14. Drug Dosing on Renal Replacement Therapy **113**
Jignesh N Shah, Vishwanath C Patil

15. Renal Replacement Therapy in Hepatorenal Syndrome **123**
Rajasekara Chakravarthi M, Vijay Varma P, Jyothsna G

16. Extracorporeal Therapies in Sepsis: An Update **130**
Ranajit Chatterjee, Ashutosh Garg

17. Extracorporeal Therapies in Poisoning **139**
Valentine Lobo

18. Nutrition for Acute Kidney Injury Patients on Renal Replacement Therapy **146**
Venkatesh Dhat

19. Renal Replacement Therapy in ICU: Infection Control and Prevention **155**
Sushma Gurav, Kapil Zirpe

Index *163*

CHAPTER 4

Renal Replacement Therapy: Nomenclature and Terminology

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INTRODUCTION

The term renal replacement therapy (RRT), when used for patients suffering from chronic kidney disease (CKD), encompasses a wide spectrum of therapies which include hemodialysis, peritoneal dialysis, and kidney transplantation. However, when discussed in relation to critically ill patients, RRT is a broad term used for various types extracorporeal therapies utilized to manage acute kidney injury (AKI) and other organ dysfunction syndromes in intensive care units (ICUs). In this chapter, we will discuss the later.

We will discuss RRT nomenclature and terminology under two major heads—dialysis process related and therapy type (Table 1). We will also briefly discuss terminologies related to other "nonrenal" extracorporeal therapies in ICUs used as multiorgan support therapies (MOST).

PROCESS RELATED

Process of dialysis is based on three basic physiological principles—diffusion, convection, and osmosis.

Table 1: Renal replacement therapy nomenclature.

Process	*Therapy type*
1. Diffusion	1. Intermittent hemodialysis (IHD)
2. Convection	2. Sustained low-efficiency dialysis (SLED)
3. Osmosis	3. *Continuous renal replacement therapy (CRRT)*: – Slow continuous ultrafiltration (SCUF) – Continuous arteriovenous hemofiltration (CAVH) – Continuous arteriovenous hemodialysis (CAVHD) – Continuous venovenous hemofiltration (CVVH) – Continuous venovenous hemodialysis (CVVHD) – Continuous venovenous hemodiafiltration (CVVHDF)

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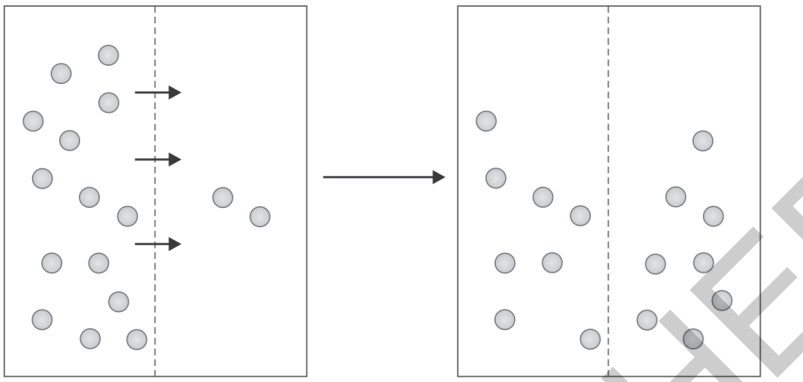


Fig. 1: Diffusion. *(For color version, see Plate 2)*

Diffusion

Diffusion is movement of solutes as a result of random molecular motions across a semipermeable membrane down its concentration gradient (Fig. 1). During hemodialysis most of the toxin removal is accomplished by diffusion. It is the best method for small solute clearance.

Convection

Ultrafiltration (UF) is the process of water removal during dialysis with the help of by transmembrane pressure gradient. Water also drags some solutes along, contributing to solute clearance. This solvent drag during UF is known as convection. It contributes to middle molecule clearance.

Osmosis

Osmosis is movement of water from low to high osmolar solution across a semipermeable membrane. This physiologic principle is utilized during peritoneal dialysis. Peritoneal cavity is filled with dialysis fluid with high osmolality which in turn helps in UF and removal of uremic toxins from the patient.

THERAPY RELATED

Intermittent Hemodialysis

Intermittent hemodialysis (IHD) is the most frequent form of RRT utilized in routine clinical practice. This therapy utilizes both diffusive and convective forms of clearances. It needs a large bore venous access. A typical IHD session runs for 3–4 hours with blood flow rate (Qb) of about 200–350 mL/min and dialysate flow rate (Qd) of 500 mL/min. UF rate depends on

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patient's hydration and hemodynamic status, but is generally around 500 mL/hr. In most cases, unfractionated heparin is utilized as anticoagulation to maintain patency of extracorporeal circuit.

Continuous Renal Replacement Therapies

Continuous renal replacement therapy (CRRT) has emerged as a dialysis technique of choice in critically ill patients.[1] As the nomenclatures itself suggests, it is a continuous form of dialysis. It is being increasingly utilized in hemodynamically unstable patients who require ongoing, large-volume fluid administration, like multiple intravenous medications or parenteral nutrition.[2] Continuous arteriovenous hemofiltration (CAVH) and continuous arteriovenous hemodialysis (CAVHD) are described as early forms of CRRT. In this technique, a direct arterial access is utilized as blood pump to the extracorporeal circuit and blood is returned back using a separate venous access. With availability of sophisticated machines, such forms of CRRT are almost obsolete and will not be discussed any further in this chapter.

Currently, large bore double lumen venous access is utilized in all forms of CRRT. Anticoagulation protocols for CRRT include use of heparin, heparin free or regional citrate anticoagulation. CRRT can be provided in various forms depending on patient specific requirements, available resources, and staff skills.[3]

Slow Continuous Ultrafiltration

Slow continuous ultrafiltration (SCUF) (Fig. 2) is used for patients with refractory fluid overload, with or without kidney disease. It is generally used for patients with refractory congestive cardiac failure. Its primary aim is to achieve safe and effective fluid removal to correct overload state. Solute removal is minimal.

Continuous Venovenous Hemofiltration

Continuous venovenous hemofiltration (CVVH) (Fig. 3) uses convection as mode of solute removal. Its primary aim is to achieve high volume UF to be replaced in part or completely with appropriate replacement fluids. CVVH is designed to achieve both solute clearance and volume control. Replacement fluid can be infused before the hemofilter (predilution method), after the

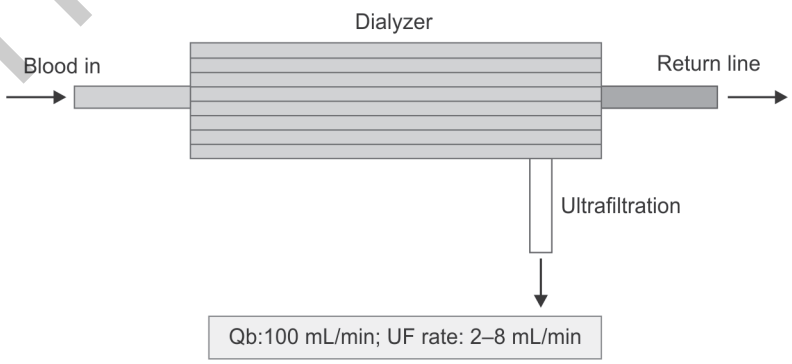


Fig. 2: Slow continuous ultrafiltration. *(For color version, see Plate 2)*

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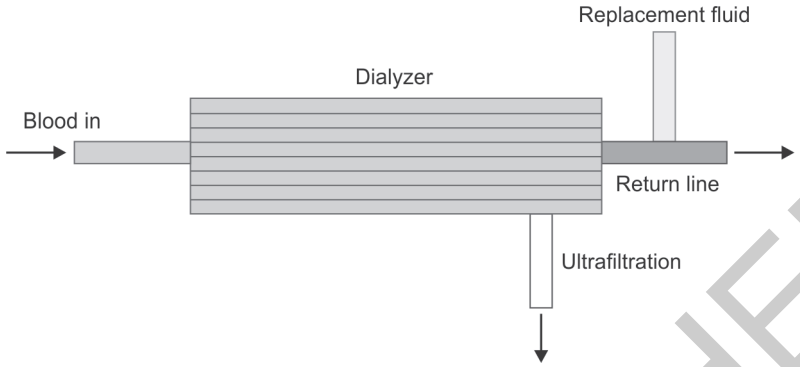


Fig. 3: Continuous venovenous hemofiltration.
(UF: ultrafiltration) *(For color version, see Plate 2)*

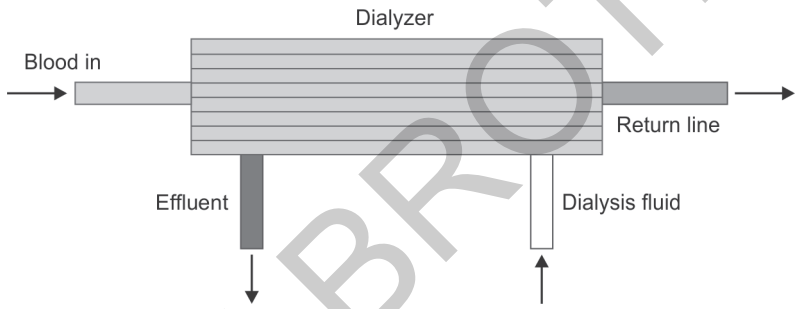


Fig. 4: Continuous venovenous hemodialysis. *(For color version, see Plate 3)*

hemofilter (postdilution method) or combination of both. A typical CVVH prescription includes Qb of 100–200 mL/min and UF rate of 600–1500 mL/hr.

Continuous Venovenous Hemodialysis

Continuous venovenous hemodialysis (CVVHD) (Fig. 4) is a continuous form of hemodialysis performed at lower Qb. It uses diffusion as mode of solute removal. Dialysis fluid runs in counter current direction to blood to achieve slow diffusive clearance. A typical CVVH prescription includes Qb of 100–200 mL/min, UF rate of 100–250 mL/hr, and dialysate flow rate of 100–300 mL/min.

Continuous Venovenous Hemodiafiltration

Continuous venovenous hemodiafiltration (CVVHDF) (Fig. 5) uses convection as mode of solute removal. Its primary aim is to achieve high volume UF to be replaced in part or completely with appropriate replacement fluids. CVVH is designed to achieve both solute clearance and volume control. Replacement fluid can be infused before the hemofilter (predilution method), after the hemofilter (postdilution method) or combination of both. A typical CVVH prescription includes Qb of 100–200 mL/min and UF rate of 600–1,500 mL/hr. Table 2 shows comparison of common CRRT subtypes with respect to infused fluids and method of solute clearance.

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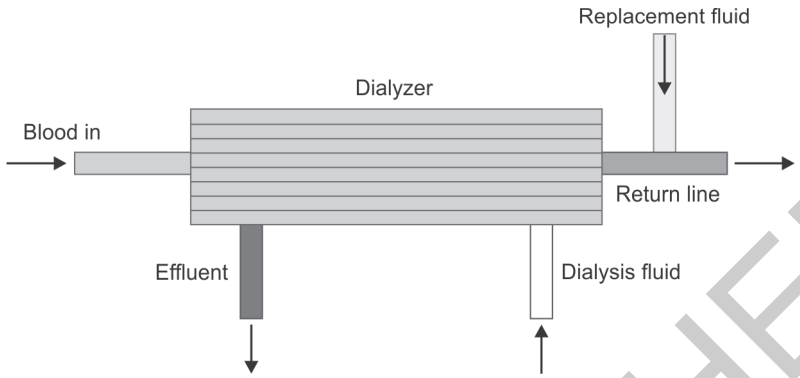


Fig. 5: Continuous venovenous hemodiafiltration. *(For color version, see Plate 3)*

Table 2: Comparison of various continuous renal replacement therapy subtypes.

	Fluids		*Method of solute clearance*	
Modality	*Dialysate*	*Replacement fluid*	*Diffusion*	*Convection*
SCUF	No	No	No	Minimal
CVVH	No	Yes	No	Yes
CVVHD	Yes	No	Yes	No
CVVHDF	Yes	Yes	Yes	Yes

(SCUF: slow continuous ultrafiltration; CVVH: continuous venovenous hemofiltration; CVVHD: continuous venovenous hemodialysis; CVVHDF: continuous venovenous hemodiafiltration)

Sustained Low-efficiency Dialysis

Sustained low-efficiency dialysis (SLED) is a hybrid treatment that provides RRT for an extended period of time, typically 6–10 hours, but is intermittent or discontinuous. SLED offers clearance through both diffusion and convection. These therapies attempt to utilize the advantages of slow therapies and minimize the disadvantages of continuous therapies. SLED offers efficient solute removal (similar to IHD) and delivers slower UF rate for hemodynamically unstable patients. Its shorter duration (compared to CRRT) offers other advantages like less anticoagulant exposure, lower costs, and decreased nurse workload.[4] It also liberates patient from machine for some hours to undergo other important diagnostic and interventional procedures if needed.

Hybrid therapies are also variably labeled as slow low-efficiency extended daily dialysis, accelerated venovenous hemofiltration (AVVH), prolonged intermittent RRT (PIRRT), extended dialysis (ED), extended daily dialysis (EDD), extended daily dialysis with filtration (EDDf), and go slow dialysis.

Sustained low-efficiency dialysis is usually performed using standard hemodialysis machine having ability to set lower dialysate flow rate (Qd). Normally, IHD machines are set to function at Qd of 500 mL/min. In SLED the desired Qd is around 100–300 mL/min. A typical SLED session runs for 6–8 hours with blood flow rate (Qb) of about 100–150 mL/min. UF rate depends on patients' hydration and hemodynamic status, and is generally around 100–250 mL/hr.

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OTHER EXTRACORPOREAL THERAPIES IN ICU

Many other extracorporeal therapies are utilized in the ICU for removal of variable toxins not cleared by conventional RRT techniques. In critically ill patients, initial impairment of one organ function is often followed by dysfunction or damage in other organs.[5] Main purpose of such therapies is to treat multiorgan dysfunction syndrome with MOST. Examples of such therapies are: therapeutic plasma exchange (TPE), extracorporeal membrane oxygenation therapy (ECMO), liver dialysis, and blood purification in sepsis

Therapeutic Plasma Exchange

Therapeutic plasma exchange is a procedure in which the patient's blood is passed through an apheresis machine, where the filtered plasma is removed and discarded with reinfusion of replacement fluid such as plasma or albumin to the patient.[6] TPE is indicated in the treatment of many neurological renal and rheumatological diseases. Recent evidences suggest its role as an adjunctive therapy in sepsis and septic shock.

Extracorporeal Membrane Oxygenation Therapy

Extracorporeal membrane oxygenation therapy is an extracorporeal technique of providing prolonged cardiac and respiratory support to patients with failing heart and lungs. The therapy aims to provide an adequate amount of gas exchange or perfusion to sustain life. ECMO is also known as extracorporeal life support.

Liver Dialysis

Liver dialysis or artificial liver support devices are designed to remove toxins accumulated in patients with liver disease. Conventional RRT removes water-soluble toxins, however, liver dysfunction leads to accumulation of lipophilic and albumin bound toxins like bilirubin, bile acids, medium-chain fatty acids, nitric oxide, amino acid metabolites, and cytokines which are not removed by hemodialysis.[7] Albumin-rich dialysate is necessary for removal of such toxins. Currently three liver dialysis systems are in use—single pass albumin dialysis, molecular adsorbent recirculating system (MARS), and fractionated plasma separation and adsorption system (Prometheus, Fresenius Medical Care, Germany).

Blood Purification in Sepsis

Sepsis is the primary cause of death in the ICU. Extracorporeal blood purification therapies have been proposed to improve outcomes for patients with sepsis. These therapies target removal of inflammatory mediators or bacterial toxins (or both) from the circulation to favorably modulate the host inflammatory response. Recent technological advances have greatly broadened the spectrum of available techniques for blood purification in sepsis.

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High-volume Hemofiltration

High-volume hemofiltration is a form of CRRT with target UF rate greater than 35 mL/kg/hr using high flux membranes. Beneficial effects of this technique are postulated to be related to removal of inflammatory cytokines during the early phase of sepsis which in turn can stop the inflammatory cascade, limit organ damage, and consequently decrease the incidence of multiorgan failure syndrome.[8]

Continuous Plasma Filtration Coupled with Adsorption

Continuous plasma filtration coupled with adsorption is a two-step detoxification therapy. In first step, a plasma filter separates plasma from the blood which is then pumped over an adsorbent cartridge containing a resin with high affinity to many cytokines, mediators, and toxins. The purified plasma is then returned to the main circuit where blood is reconstituted. The plasma passes through the adsorbent cartridge with a lower velocity than the blood flow which allows more efficient removal of inflammatory mediators.[9]

Hemoperfusion

Hemoperfusion involves placement of a sorbent cartridge in series with the filter in order to remove those toxins that are not removable by classic CRRT. The sorbent is placed in direct contact with blood and toxin removal characteristics of hemoperfusion are dependent on the types of sorbent used. Polymyxin (PMX)-hemoperfusion utilizes PMX B-coated fibers in a cartridge with high affinity for lipopolysaccharide which helps in removal of circulating endotoxin.[10]

The CytoSorb adsorber, which is approved for use in European market and also available in India, is composed of biocompatible porous polymer beads that act like tiny sponges to remove substances from whole blood based on pore capture and surface adsorption. This technique is also designed to reduce cytokine burden during sepsis.

SUMMARY

Incidence of acute kidney injury in critically ill patients is steadily increasing. Development of AKI is associated with increased morbidity and mortality. Familiarity with various renal replacement modalities and associated terminologies is essential for all intensive care physicians.

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Workbook on Renal Replacement Therapy in ICU

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- The book *Workbook on Renal Replacement Therapy in ICU* is designed as a workbook which will serve as a practical guide for beginners in intensive care and nephrologists who are dealing with critically ill patients on a day-to-day basis.
- Comprehensive workbook dealing with care of ICU patients on renal replacement therapy.
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- Equipped with illustrations/flow charts

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