336 Dialysis in the Treatment of Renal Failure

Kathleen D. Liu, Glenn M. Chertow

Dialysis may be required for the treatment of either acute or chronic kidney disease. The use of continuous renal replacement therapies (CRRTs) and slow low-efficiency dialysis (SLED) is specific to the management of acute renal failure and is discussed in Chap. 334. These modalities are performed continuously (CRRT) or over 6–12 h per session (SLED), in contrast to the 3–4 h of an intermittent hemodialysis session. **Advantages and disadvantages of CRRT and SLED are discussed in Chap. 334.**

Peritoneal dialysis is rarely used in developed countries for the treatment of acute renal failure because of the increased risk of infection and (as will be discussed in more detail below) less efficient clearance per unit of time. The focus of this chapter will be on the use of peritoneal and hemodialysis for end-stage renal disease (ESRD).

With the widespread availability of dialysis, the lives of hundreds of thousands of patients with ESRD have been prolonged. In the United States alone, there are now approximately 615,000 patients with ESRD, the vast majority of whom require dialysis. The incidence rate for ESRD is 357 cases per million population per year. The incidence of ESRD is disproportionately higher in African Americans (940 per million population per year) as compared with white Americans (280 per million population per year). In the United States, the leading cause of ESRD is diabetes mellitus, currently accounting for nearly 45% of newly diagnosed cases of ESRD. Approximately 30% of patients have ESRD that has been attributed to hypertension, although it is unclear whether in these cases hypertension is the cause or a consequence of vascular disease or other unknown causes of kidney failure. Other prevalent causes of ESRD include glomerulonephritis, polycystic kidney disease, and obstructive uropathy.

Globally, mortality rates for patients with ESRD are lowest in Europe and Japan but very high in the developing world because of the limited availability of dialysis. In the United States, the mortality rate of patients on dialysis has decreased slightly but remains extremely high, with a 5-year survival rate of approximately 35–40%. Deaths are due mainly to cardiovascular diseases and infections (approximately 40 and 10% of deaths, respectively). Older age, male sex, nonblack race, diabetes mellitus, malnutrition, and underlying heart disease are important predictors of death.

TREATMENT OPTIONS FOR ESRD PATIENTS

Commonly accepted criteria for initiating patients on maintenance dialysis include the presence of uremic symptoms, the presence of hyperkalemia unresponsive to conservative measures, persistent extracellular volume expansion despite diuretic therapy, acidosis refractory to medical therapy, a bleeding diathesis, and a creatinine clearance or estimated glomerular filtration rate (GFR) below 10 mL/min per 1.73 m^2 (see Chap. 335 for estimating equations). Timely referral to a nephrologist for advanced planning and creation of a dialysis access, education about ESRD treatment options, and management of the complications of advanced chronic kidney disease (CKD), including hypertension, anemia, acidosis, and secondary hyperparathyroidism, are advisable. Recent data have suggested that a sizable fraction of ESRD cases result following episodes of acute renal failure, particularly among persons with underlying CKD. Furthermore, there is no benefit to initiating dialysis preemptively at a GFR of 10–14 mL/min per 1.73 m^2 compared to initiating dialysis for symptoms of uremia.

In ESRD, treatment options include hemodialysis (in center or at home); peritoneal dialysis, as either continuous ambulatory peritoneal dialysis (CAPD) or continuous cyclic peritoneal dialysis (CCPD); or transplantation (Chap. 337). Although there are significant geographic variations and differences in practice patterns, hemodialysis remains the most common therapeutic modality for ESRD (>90% of patients) in the United States. In contrast to hemodialysis, peritoneal dialysis is continuous, but much less efficient, in terms of solute clearance. Although no large-scale clinical trials have been completed comparing outcomes among patients randomized to either hemodialysis or peritoneal dialysis, outcomes associated with both therapies are similar in most reports, and the decision of which modality to select is often based on personal preferences and quality-of-life considerations.

HEMODIALYSIS

Hemodialysis relies on the principles of solute diffusion across a semipermeable membrane. Movement of metabolic waste products takes place down a concentration gradient from the circulation into the dialysate. The rate of diffusive transport increases in response to several factors, including the magnitude of the concentration gradient, the membrane surface area, and the mass transfer coefficient of the membrane. The latter is a function of the porosity and thickness of the membrane, the size of the solute molecule, and the conditions of flow on the two sides of the membrane. According to laws of diffusion, the larger the molecule, the slower is its rate of transfer across the membrane. A small molecule, such as urea (60 Da), undergoes substantial clearance, whereas a larger molecule, such as creatinine (113 Da), is cleared less efficiently. In addition to diffusive clearance, movement of waste products from the circulation into the dialysate may occur as a result of ultrafiltration. Convective clearance occurs because of solvent drag, with solutes being swept along with water across the semipermeable dialysis membrane.

THE DIALYZER

There are three essential components to hemodialysis: the dialyzer, the composition and delivery of the dialysate, and the blood delivery system (Fig. 336-1). The dialyzer is a plastic chamber with the ability to perfuse blood and dialysate compartments simultaneously at very high flow rates. The hollow-fiber dialyzer is the most common in use in the United States. These dialyzers are composed of bundles of capillary tubes through which blood circulates while dialysate travels on the outside of the fiber bundle. The majority of dialyzers now manufactured in the United States are "biocompatible" synthetic membranes derived from polysulfone or related compounds (versus older cellulose "bioincompatible" membranes that activated the complement cascade). The frequency of reprocessing and reuse of hemodialyzers and blood lines varies across the world. In general, as the cost of disposable supplies has decreased, their use has increased. Formaldehyde, peracetic acid–hydrogen peroxide, glutaraldehyde, and bleach have all been used as reprocessing agents.

DIALYSATE

The potassium concentration of dialysate may be varied from 0 to 4 mmol/L depending on the predialysis serum potassium concentration. The usual dialysate calcium concentration is 1.25 mmol/L (2.5 meq/L), although modification may be required in selected settings (e.g., higher dialysate calcium concentrations may be used in patients with hypocalcemia associated with secondary hyperparathyroidism or following parathyroidectomy). The usual dialysate sodium concentration is 136–140 mmol/L. In patients who frequently develop hypotension during their dialysis run, "sodium modeling" to counterbalance urea-related osmolar gradients is often used. With sodium modeling, the dialysate sodium concentration is gradually lowered from the range of 145–155 mmol/L to isotonic concentrations (136–140 mmol/L) near the end of the dialysis treatment, typically declining either in steps or in a linear or exponential fashion. Higher dialysate sodium concentrations and sodium modeling may predispose patients to positive sodium balance and increased thirst; thus, these strategies to ameliorate intradialytic hypotension may be undesirable in hypertensive patients or in patients with large interdialytic weight gains. Because patients are exposed to approximately 120 L of water during each dialysis treatment, water used for the dialysate is subjected to filtration, softening, deionization, and, ultimately, reverse osmosis to remove microbiologic contaminants and dissolved ions.