Hemodialysis is a life-sustaining procedure for the treatment of patients with end-stage renal disease. In acute renal failure the procedure provides for rapid correction of fluid and electrolyte abnormalities that pose an immediate threat to the patient’s well-being. In chronic renal failure, hemodialysis results in a dramatic reversal of uremic symptoms and helps improve the patient’s functional status and increase patient survival. To achieve these goals the dialysis prescription must ensure that an adequate amount of dialysis is delivered to the patient.

Numerous studies have shown a correlation between the delivered dose of hemodialysis and patient morbidity and mortality [1–4]. Therefore, the delivered dose should be measured and monitored routinely to ensure that the patient receives an adequate amount of dialysis. One method of assessing the amount of dialysis delivered is to calculate the $Kt/V$. The $Kt/V$ is a unitless value that is indicative of the dose of hemodialysis. The $Kt/V$ is best described as the fractional clearance of urea as a function of its distributional volume. The fractional clearance is operationally defined as the product of dialyzer clearance ($K$) and the treatment time ($t$). Recent guidelines suggest that the $Kt/V$ be determined by either formal urea kinetic modeling using computational software or by use of the $Kt/V$ natural logarithm formula [5]. The delivered dose also may be assessed using the urea reduction ratio (URR).

A number of factors contribute to the amount of dialysis delivered as measured by either the $Kt/V$ or URR. Increasing blood flow rates to 400 mL/min or higher and increasing dialysate flow rates to 800 mL/min are effective ways to increase the amount of delivered dialysis. When increases in blood and dialysate flow rates are no longer effective, use of a high-efficiency membrane can further increase the dose of dialysis ($KoA >600 \text{ mL/min}$, where $KoA$ is the constant indicating the efficiency of dialyzers in removing urea). Eventually, increases in blood and dialysate flow rates, even when combined with a high-efficiency membrane, result in no further increase in the urea clearance rate. At this point the most important determinant affecting the dose of dialysis is the amount of time the patient is dialyzed.
Dialysis as Treatment of End-Stage Renal Disease

Ultrafiltration during dialysis is performed to remove volume that has accumulated during the interdialytic period so that patients can be returned to their dry weight. Dry weight is determined somewhat crudely, being based on clinical findings. The patient’s dry weight is the weight just preceding the development of hypotension. The patient should be normotensive and show no evidence of pulmonary or peripheral edema. A patient’s dry weight frequently changes over time and therefore must be assessed regularly to avoid hypotension or progressive volume overload.

During ultrafiltration the driving force for fluid removal is the establishment of a pressure gradient across the dialysis membrane. The water permeability of a dialysis membrane is a function of membrane thickness and pore size and is indicated by its ultrafiltration coefficient (KUF). During ultrafiltration additional solute removal occurs by solvent drag or convection. Because of increased pore size, high-flux membranes (KUF >20 mL/h/mm Hg) are associated with much higher clearances of average to high molecular weight solutes such as β2 microglobulin. Because blood flow rates over 50 to 100 mL/min result in little or no further increase in the clearance of these molecules, clearance is primarily membrane-limited. In contrast, clearance values for urea are not significantly greater with a high-flux membrane compared with a high-efficiency membrane because the blood flow rate, and not the membrane, is the principal determinant of small solute clearance.

The biocompatibility of the dialysis membrane is another consideration in the dialysis prescription. A biocompatible dialysis membrane is one in which minimal reaction occurs between the humoral and cellular components of blood as they come into contact with the surface of the dialyzer [6]. One such reaction that has been used as a marker of biocompatibility is evidence of complement activation. Cellulosic membranes generally tend to be bioincompatible, whereas noncellulosic or synthetic membranes have more biocompatible characteristics. Whether any clinical difference exists in acute or chronic outcomes between biocompatible and bioincompatible membranes is still a matter of debate. Trials designed to address this issue have been mostly uncontrolled, limited in sample size, and often retrospective in nature. Nevertheless, some evidence exists to suggest that bioincompatible membranes may have a greater association with β2 microglobulin-induced amyloidosis, susceptibility to infection, enhanced protein catabolism, and increased patient mortality [5–9].

Another aspect of the dialysis prescription is the composition of the dialysate. The concentrations of sodium, potassium, calcium, and bicarbonate in the dialysate can be individualized such that ionic composition of the body is restored toward normal during the dialytic procedure. This topic is discussed in detail in chapter 2.

Although hemodialysis is effective in removing uremic toxins and provides adequate control of fluid and electrolyte abnormalities, the procedure does not provide for the endocrine or metabolic functions of the normal kidney. Therefore, the dialysis prescription often includes medications such as erythropoietin and 1,25(OH)2 vitamin D. The dose of erythropoietin should be adjusted to maintain the hematocrit between 33% and 36% (hemoglobin of 11 g/dL and 12 g/dL, respectively) [10]. Vitamin D therapy is often used in patients undergoing dialysis to help limit the severity of secondary hyperparathyroidism. Dosages usually range from 1 to 2 µg given intravenously with each treatment.

![Diffusional and convective flux in hemodialysis](image)
During hemodialysis water moves from blood to dialysate driven by a hydrostatic pressure gradient between the blood and dialysate compartments, a process referred to as ultrafiltration. The rate of ultrafiltration is determined by the magnitude of this pressure gradient. Movement of water tends to drag solute across the membrane, a process referred to as convective transport or solvent drag. The contribution of convective transport to total solute transport is only significant for average-to-high molecular weight solutes because they tend to have a smaller diffusive flux.

Acceptable methods to measure hemodialysis adequacy:

- Formal urea kinetic modeling (Kt/V) using computational software
- \( Kt/V = \ln \left( \frac{R}{H_{11002}} \right) + \frac{4.35 \times R}{Uf/w} \)
- Urea reduction ratio

Recommended by the National Kidney Foundation Dialysis Outcomes Quality Initiative Clinical Practice Guidelines, which suggest a prescribed minimum Kt/V of 1.3 and a minimum urea reduction ratio of 70%.

\( \ln \) is the natural logarithm; \( R \) is postdialysis blood urea nitrogen (BUN)/predialysis BUN; \( t \) is time in hours; \( Uf \) is ultrafiltration volume in liters; \( w \) is postdialysis weight in kilograms.

The common treatments for hemodynamic instability of patients undergoing dialysis. It is important to begin by excluding reversible causes associated with hypotension because failure to recognize these abnormalities can be lethal. Perhaps the most common reason for hemodynamic instability is an inaccurate setting of the dry weight. Once these conditions have been dealt with, the use of a high sodium dialysate, sodium modeling, cool temperature dialysis, and perhaps the administration of midodrine may be attempted. All of these maneuvers are effective in stabilizing blood pressure in dialysis patients.

Acceptable methods to measure hemodialysis adequacy as recommended in the Dialysis Outcomes Quality Initiative (DOQI) Clinical Practice Guidelines. These guidelines may change as new information on the benefit of increasing the dialysis prescription becomes available. For the present, however, they should be considered the minimum targets.