Chapter 1

NORMAL AND ABNORMAL KIDNEY FUNCTION

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The kidneys are essential organs in the body which function to remove water and waste products. They also produce important hormones such as erythropoietin, Vitamin D, and renin.

The kidneys are located in the back of the abdomen, one on each side of the spinal column, at about the level of the lower ribs. The average weight of an adult human kidney is approximately one-quarter pound. Each kidney is approximately 4 inches long, 2.5 inches wide, and 1.5 inches thick.

The kidney receives about 20 percent of the blood coming from the heart each time it beats. The rate of blood flow through both kidneys is approximately 1.2 liters per minute.

The basic functioning unit of the kidney is called the *nephron*. The kidneys together comprise greater than 2 million nephrons, and each is capable of forming urine. The nephron's function is to clean the blood of unwanted substances as it flows past. The nephron is composed of the *glomeruli*, through which the blood is filtered, and then the *tubules*, which receive and process the filtered fluid. Kidney function is estimated using the *glomerular filtration rate* or GFR. This is the amount of filtrate formed in all nephrons.

The normally functioning kidney controls the concentration of body fluids. It accomplishes this by excreting excessive amounts of water in the urine if body fluids are too dilute or by excreting excessive solutes when body fluids are too concentrated. Despite large intakes of salt and water, almost no change in blood volume or concentration occurs. Another important function is acid-base balance. The body maintains a constant pH via several buffering mechanisms. The kidney plays a major role in this by the net excretion of hydrogen ions when the blood is too acidic and the net excretion of bicarbonate ions when the blood is too alkaline.

The kidneys also have a hormonal role. They are in part responsible for the conversion of Vitamin D to its active metabolite, which is important in the absorption of calcium from the intestine. *Erythropoietin* is

manufactured by the kidney and stimulates the bone marrow to produce red blood cells. With renal failure there is decreased production of this hormone and anemia results. With a decreased number of red blood cells and therefore fewer cells to carry oxygen to the tissues, patients may tire easily and become short of breath after only minimal activity. Often patients benefit by taking injections of synthetic erythropoietin to achieve and improved blood count (see Chapter 19). *Renin* is another kidney-produced hormone that is important in sodium and blood pressure control.

Renal failure occurs from a variety of causes, and the time course and clinical symptoms vary from individual to individual. A person's kidney failure may occur suddenly or progress slowly over a period of many years. As failure progresses the kidney is less able to maintain a steady volume and concentration of body fluids. For many, as fluid and salt become increasingly difficult to remove, high blood pressure occurs as well as *edema* or fluid in the tissues. Patients may have problems with swelling of their legs and shortness of breath from accumulation of fluid in the lungs (*pulmonary edema*). Medications may be necessary to control blood pressure and assist in fluid removal (diuretics). The kidneys also are no longer able to excrete the waste products of metabolism, and substances such as potassium and phosphorus can accumulate in the body. Elevated phosphorus levels cause calcium levels in the blood to fall and result in the stimulation of a hormone from the parathyroid glands. This hormone increases the release of calcium from bones and if not suppressed can result in bone pain and progress to weakened and demineralized bones.

As failure progresses patients are required to modify their diets—usually decreasing sodium, potassium, and phosphorus intake and ultimately restricting fluids. Patients will generally need to take phosphate binders as well as Vitamin D supplements.

As waste products accumulate, patients may have problems with fatigue, headaches, nausea, vomiting, and decreased appetite resulting in weight loss. Itching may also be prominent if the body's phosphorus levels are high. Patients may note a decreased ability to concentrate. Finally, there may be an increased tendency to bleed.

The decision to start hemodialysis is based on a combination of symptoms and laboratory data. Emergent indications to start are encephalopathy (change in mental status), seizures, and coma due to uremia, as well as severe hyperkalemia (elevated potassium), acidosis, pericarditis (or inflammation of the heart lining) from accumulated toxins, and pulmonary edema which no longer responds to medications. Most patients reach the need to initiate on hemodialysis gradually. The goal is to begin when a patient's symptoms are no longer responsive to conservative management and before there are serious complications. Practically speaking, most patients will start dialysis when the creatinine clearance (CRCI) is very low, 3–5 cc per minute (normal 100 cc per minute) and the serum creatinine is greater than 12–14 mg/dl (normal 1.0 mg/dl). These are not absolute numbers, however, and must be carefully interpreted for the individual patient. In a small person, a creatinine of 5 mg/dl may represent a level of function which requires dialysis.

Fortunately, if your kidneys fail there is a choice of treatments to sustain your life. Options available are hemodialysis, forms of peritoneal dialysis (refer to Chapter 3), and transplantation (refer to Chapter 11).