25

Renal Structure and Function

Orson W. Moe and Javier A. Neyra

INTRODUCTION

The kidney maintains the composition and quantity of body fluids, and its failure is manifested by dysfunction of multiple organs. Chronic kidney disease is approaching epidemic proportions worldwide, and acute kidney injury in the inpatient setting affects a very high percentage of hospital admissions with a high mortality rate. The etiologies of these conditions are very diverse. In addition to loss of glomerular filtration, kidney diseases include hypertension, urolithiasis, and a host of electrolyte disorders that do not affect the glomerular filtration rate (GFR) but nonetheless cause significant morbidity and mortality. To understand these conditions, a thorough knowledge of the anatomy and function of the kidney is requisite.

Approximately 25% of the cardiac output is distributed to the kidneys, where the blood is continuously cleansed. In addition to excretion, the kidney is an important metabolic organ and a source of endocrine molecules. Renal failure represents a disruption of all three of these functions. Selected aspects of renal structure and function are reviewed briefly in this chapter to set the foundation for the subsequent chapters that deal with specific renal diseases.

RENAL STRUCTURE

Macroscopic Anatomy

The kidneys are seated against the posterior wall of the abdomen in the retroperitoneal space, making them readily accessible for percutaneous biopsy. The lower poles may be palpable on deep inspiration in a lean individual. Each human kidney weighs about 120 to 170 g; is about 11 cm long, 6 cm wide, and 3 cm thick; and is endowed with approximately 1 million nephrons. There are interindividual variations. The "kidney size" commonly referred to in clinical sonographic reports is actually the cephalocaudal renal length, which is not a perfect surrogate for renal volume and mass.

The kidney is surrounded by a fibrous capsule. The renal arteries enter the kidney and the renal vein and ureters leave the kidney in the renal pelvis. The bisected surface consists of the lighter-colored outer *cortex* and the darker inner *medulla* (Fig. 25-1). A sample from a clinical biopsy typically originates from the cortex in the lower pole. The medulla is divided into outer and inner regions, and the outer medulla is subdivided into outer and inner stripes. The medulla has multiple conical contours, called *pyramids*, with their apices abutting on the renal pelvis as papillae. The contact points of the renal pelvis with the renal papillae are cup-like structures called *calyces*. Interpolated between the pyramids are centripetal extensions of cortical tissue called *columns of Bertin*.

Renal Circulation

Each kidney receives blood from a single renal artery, although supernumerary arteries are present in up to one third of individuals. Just before or after the renal artery enters the kidney, it divides into interlobar arteries that pass between the pyramids of the kidney radially up the columns of Bertin (see Fig. 25-1A). The interlobar arteries further divide into arcuate arteries which arch along the corticomedullary junction (see Fig. 25-1B). Arcuate arteries give rise to cortical ascending arteries, which bring blood to the glomeruli. Afferent arterioles ramify into glomerular capillaries, distributing blood to individual glomeruli. Features of the renal circulation are summarized in Table 25-1.

The glomerular capillary is the site for glomerular ultrafiltration. Even though the efferent arteriole is downstream from the glomerular capillary, it is not a venule because it has arteriolar walls and is upstream of the second capillary system surrounding the tubules. The peritubular capillaries provide oxygen and nutrients for the kidney, collect the fluid and solutes reabsorbed by tubules to return into the circulation, and deliver the solutes to be secreted by tubule into the tubule fluid. The peritubular capillaries surrounding the cortical and juxtamedullary nephrons originate from the efferent arterioles of cortical and juxtamedullary glomeruli, respectively.

The vessels that run parallel to loops of Henle are called *vasa recta* (see Fig. 25-1D) because of their long, straight structures. Blood from the peritubular capillaries is returned to the circulation by a venous system that mirrors the architectural structure of the arterial supply: interlobular vein, arcuate vein, interlobar vein, and renal vein. The parallel countercurrent nature of the vasculature provides the basis for the very high medullar tonicity, which allows urine concentration but also direct arteriovenous diffusion of oxygen, giving rise to the very low oxygen tension in the medulla. This low oxygen tension renders the kidney prone to ischemic injury, which is one of the most common causes of acute kidney injury (see Chapter 31).

Renal Nerves

The capsules of the kidney and the ureters have pain fibers derived from splanchnic nerves. This explains the costovertebral angle pain that occurs when the kidneys are inflamed and during renal colic. The renal parenchyma does not have pain fibers but is richly innervated with sympathetic nerves that enter the renal parenchyma with the renal artery. The sympathetic nerves abut on the arterioles (see Fig. 25-1C), stimulate renin release,