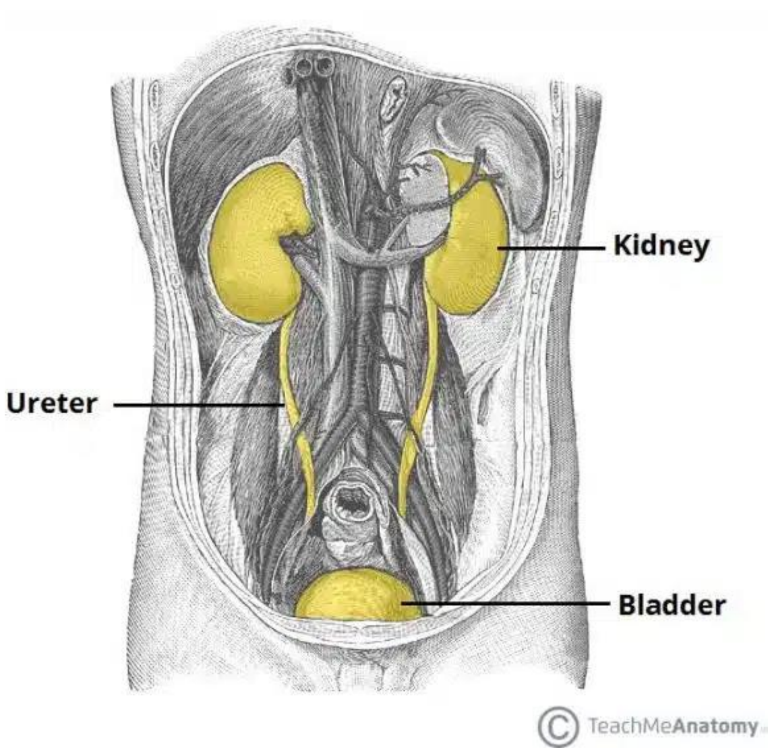
KARNATAKA RADIOLOGY EDUCATION PROGRAM

Anatomy and Applied Radiology Kidneys – 1

The kidneys are bilateral bean-shaped organs, reddish-brown in colour and located in the posterior abdomen. Their main function is to filter and excrete waste products from the blood. They are also responsible for water and electrolyte balance in the body.

Metabolic waste and excess electrolytes are excreted by the kidneys to form urine. Urine is transported from the kidneys to the bladder by the ureters. It leaves the body via the urethra, which opens out into the perineum in the female and passes through the penis in the male.

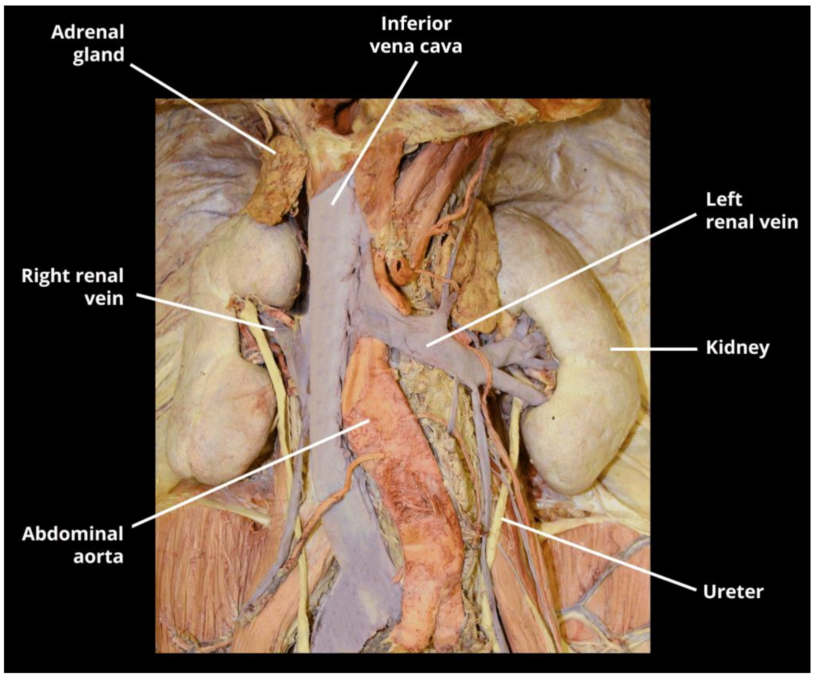


Anatomical Position

The kidneys lie retroperitoneally (behind the peritoneum) in the abdomen, either side of the vertebral column.

They typically extend from T12 to L3, although the right kidney is often situated slightly lower due to the presence of the liver. Each kidney is approximately three vertebrae in length.

The adrenal glands sit immediately superior to the kidneys within a separate envelope of the renal fascia.



Kidney Structure

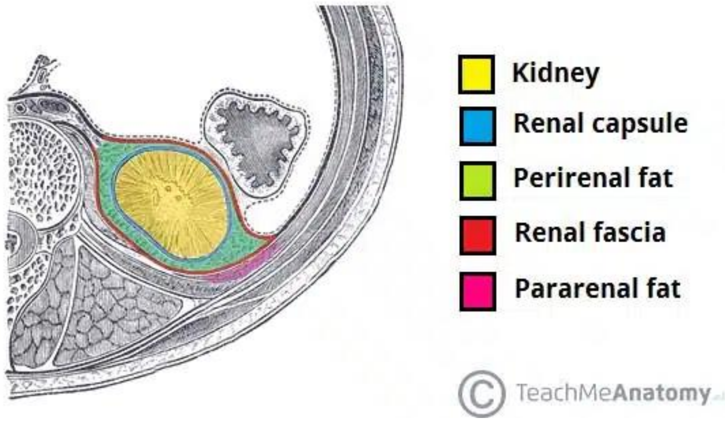
The kidneys are encased in complex layers of fascia and fat. They are arranged as follows (deep to superficial):

Renal capsule – tough fibrous capsule.

Perirenal fat – collection of extraperitoneal fat.

Renal fascia (also known as Gerota's fascia or perirenal fascia) – encloses the kidneys and the suprarenal glands.

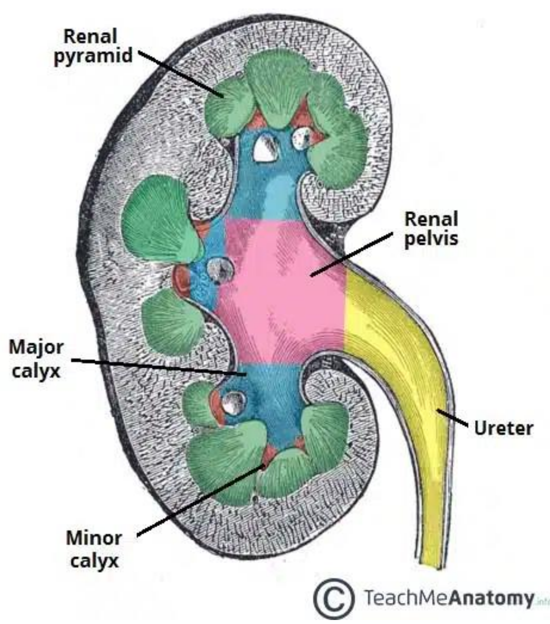
Pararenal fat – mainly located on the posterolateral aspect of the kidney



Internally, the kidneys have an intricate and unique structure. The renal parenchyma can be divided into two main areas – the outer cortex and inner medulla. The cortex extends into the medulla, dividing it into triangular shapes – these are known as renal pyramids.

The apex of a renal pyramid is called a renal papilla. Each renal papilla is associated with a structure known as the minor calyx, which collects urine from the pyramids. Several minor calices merge to form a major calyx. Urine passes through the major calices into the renal pelvis, a flattened and funnel-shaped structure. From the renal pelvis, urine drains into the ureter, which transports it to the bladder for storage.

The medial margin of each kidney is marked by a deep fissure, known as the renal hilum. This acts as a gateway to the kidney – normally the renal vessels and ureter enter/exit the kidney via this structure.



Anatomical Relations

The kidneys sit in close proximity to many other abdominal structures which are important to be aware of clinically:

	Anterior	Posterior
Left	• Suprarenal gland • Spleen • Stomach • Pancreas • Left colic flexure • Jejunum	• Diaphragm • 11th and 12th ribs • Psoas major, quadratus lumborum and transversus abdominis • Subcostal, iliohypogastric and ilioinguinal nerves
Right	• Suprarenal gland • Liver • Duodenum • Right colic flexure	• Diaphragm • 12th rib • Psoas major, quadratus lumborum and transversus abdominis • Subcostal, iliohypogastric and ilioinguinal nerves

Arterial Supply

The kidneys are supplied with blood via the renal arteries, which arise directly from the abdominal aorta, immediately distal to the origin of the superior mesenteric artery. Due to the anatomical position of the abdominal aorta (slightly to the left of the midline), the right renal artery is longer, and crosses the vena cava posteriorly.

The renal artery enters the kidney via the renal hilum. At the hilum level, the renal artery forms an anterior and a posterior division, which carry 75% and 25% of the blood supply to the kidney, respectively. Five segmental arteries originate from these two divisions.

The avascular plane of the kidney (line of Brodel) is an imaginary line along the lateral and slightly posterior border of the kidney, which delineates the segments of the kidney supplied by the anterior and posterior divisions. It is an important access route for both open and endoscopic surgical access of the kidney, as it minimises the risk of damage to major arterial branches.

Note: The renal artery branches are anatomical end arteries – there is no communication between vessels. This is of crucial importance; as trauma or obstruction in one arterial branch will eventually lead to ischaemia and necrosis of the renal parenchyma supplied by this vessel.

The segmental branches of the renal undergo further divisions to supply the renal parenchyma:

Each segmental artery divides to form interlobar arteries. They are situated either side every renal pyramid.

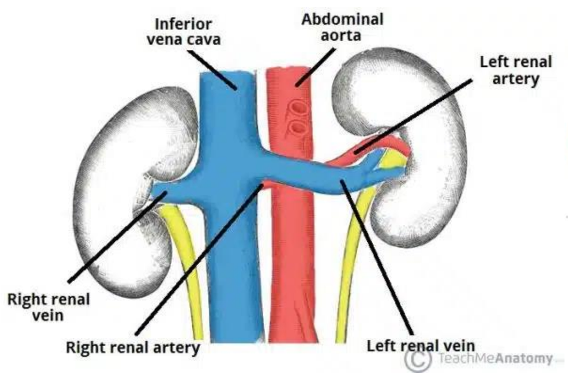
These interlobar arteries undergo further division to form the arcuate arteries.

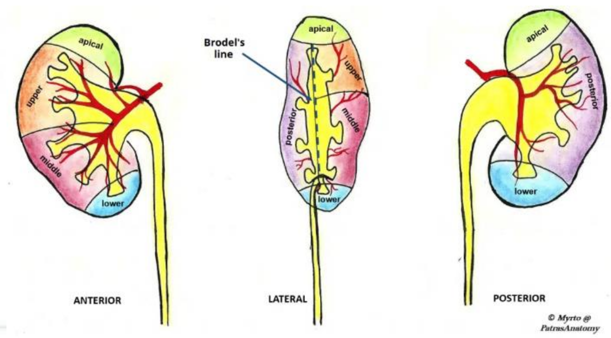
At 90 degrees to the arcuate arteries, the interlobular arteries arise.

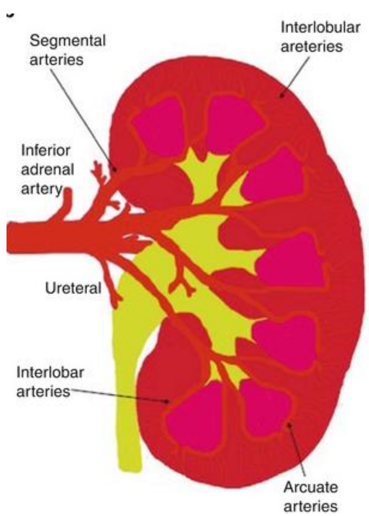
The interlobular arteries pass through the cortex, dividing one last time to form afferent arterioles.

The afferent arterioles form a capillary network, the glomerulus, where filtration takes place. The capillaries come together to form the efferent arterioles.

In the outer two-thirds of the renal cortex, the efferent arterioles form what is a known as a peritubular network, supplying the nephron tubules with oxygen and nutrients. The inner third of the cortex and the medulla are supplied by long, straight arteries called vasa recta.



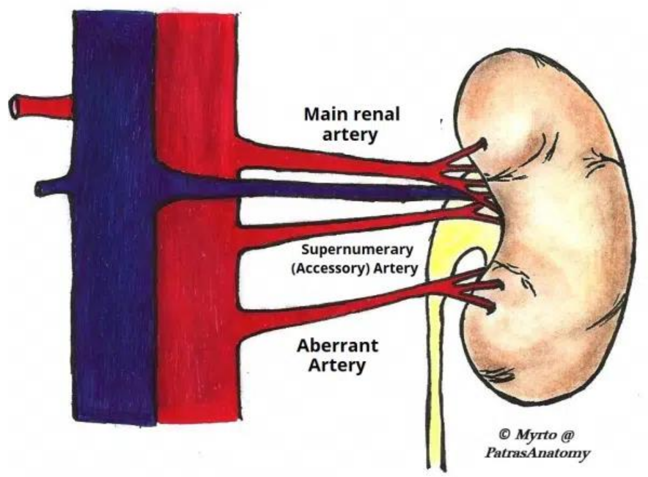




Variation in Arterial Supply to the Kidney

The kidneys present a great variety in arterial supply; these variations may be explained by the ascending course of the kidney in the retroperitoneal space, from the original embryological site of formation (pelvis) to the final destination (lumbar area). During this course, the kidneys are supplied by consecutive branches of the iliac vessels and the aorta.

Usually the lower branches become atrophic and vanish while new, higher ones supply the kidney during its ascent. Accessory arteries are common (in about 25% of patients). An accessory artery is any supernumerary artery that reaches the kidney. If a supernumerary artery does not enter the kidney through the hilum, it is called aberran



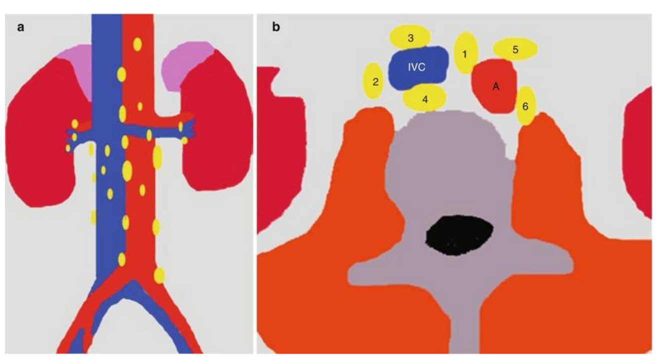
Venous Drainage

The kidneys are drained of venous blood by the left and right renal veins. They leave the renal hilum anteriorly to the renal arteries, and empty directly into the inferior vena cava.

As the vena cava lies slightly to the right, the left renal vein is longer, and travels anteriorly to the abdominal aorta below the origin of the superior mesenteric artery. The right renal artery lies posterior to the inferior vena cava.

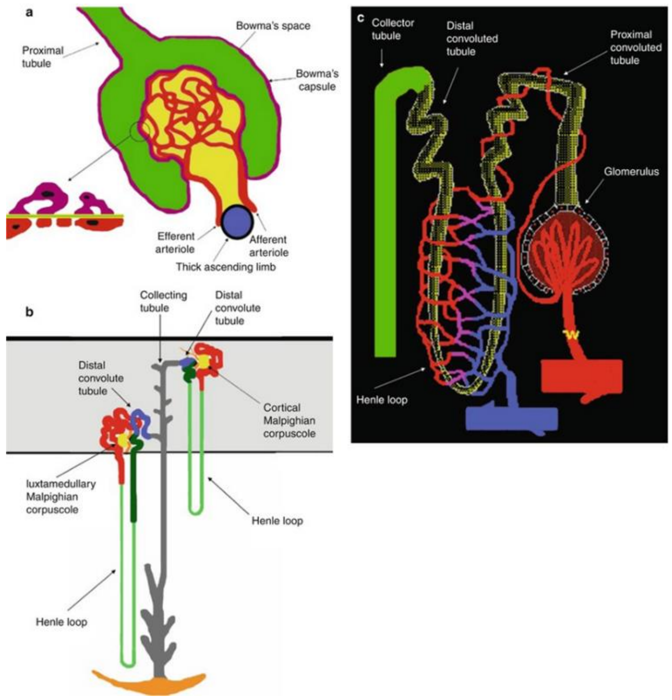
Lymphatics

Lymph from the kidney drains into the lateral aortic (or para-aortic) lymph nodes, which are located at the origin of the renal arteries.



Normal Renal Physiology

The principal function of the mammalian kidney is to maintain homeostasis or equilibrium between our internal volume and electrolyte status and that of the environment's influences, diet, and intake. It functions to maintain our intra- and extracellular fluid status at a constant, despite the wide variety of daily fluid and electrolyte intake. In man, the kidneys consist of two to three million nephrons and weigh only 250–300 g.



The kidneys' extraordinary excretory and regulatory objectives are achieved through the processes of glomerular ultrafiltration, tubular reabsorption, and tubular secretion. To a large extent, these excretory and regulatory processes depend on the blood supply to the kidneys.

The kidneys receive the highest blood flow per gram of organ weight in the body at 1 L/min. The renal blood flow is to consider the renal fraction, which corresponds to the fraction of the total cardiac output that flows through the kidneys. The kidneys are highly vascularized parenchymas, and a 70-kg man with a cardiac output of 6 L/min has a normal renal blood flow of about 1.2 L/min corresponding to 20 % of the cardiac output. Considering the fact that each kidney in a normal 70-kg man weighs about 130–170 g, for a total weight of about 300 g of kidney, the average flow per gram of kidney weight (perfusion value) is about 400 mL/min/100 g. This is several times greater per unit weight of organ than the blood flow through most other organs. During various stress conditions or diseases, this renal fraction can vary considerably and be markedly affected. Blood flow to the kidneys will be dependent on a number of important systemic factors. Clearly, if there is a problem with volume (dehydration, hemorrhage) or cardiac output (congestive heart failure, myocardial infarct), blood flow is diminished. In less obvious ways, hypoalbuminemia (cirrhosis, nephrotic

syndrome, and starvation) affects the intravascular volume so that the effective blood (volume) flow is diminished, despite many of these patients appearing with total body fluid overloaded. Finally, hypotension from severe vasodilatation (anaphylactic shock, sepsis) would also diminish blood flow to the kidneys.

Oxygen consumption by the kidneys is quite high and amounts to about 8 % of the total oxygen consumption of the body. Oxygen delivery to any organ is directly dependent on hemoglobin content (blood) and cardiac output (blood flow). As in other tissues, an important function of blood flow is to provide adequate oxygenation and nutrition. Therefore, the relatively high blood flow to the kidneys exists to feed its metabolic demands as well as to allow ultrafiltration. In fact, the renal blood flow is so high that only a small percent of the available oxygen is extracted from the blood perfusing the kidneys.

Compiled by: Dr Pravin G U Principal, Prof.RadioDiagnosis . Sri Chamundeshwari Medical college Hospital & Research Institute,Channapatna,Karnataka.President IRIA Karnataka.

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