# Anatomy of the kidney and ureter

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**Abstract**

The urinary tract is divided into upper and lower parts. The kidneys and ureters make up the upper urinary tract while the urinary bladder and urethra constitute the lower urinary tract. This classification while somewhat arbitrary is nevertheless useful and convenient for descriptive purposes. In this article, a detailed description of the topographical and vascular anatomy of the kidney and ureter is followed by a brief account of the anatomy of the suprarenal gland.

**Keywords** Pelvicalyceal system; renal fascia; renal sinus; suprarenal glands; ureter; urothelium

## 1

The upper urinary tract is a collective term that denotes the pelvicalyceal system of the kidney and the ureter. The kidneys are retroperitoneal organs that lie high on the posterior abdominal wall, one on either side of the vertebral column, level with the bodies of the 12$^{th}$ thoracic and upper three lumbar vertebrae. The right kidney lies at a slightly lower level than the left kidney, presumably on account of the bulk of the overlying liver (Figure 1).

Each adult kidney is 12 cm in length, 6 cm in width and 3 cm in anteroposterior dimension. The left kidney is usually slightly longer and somewhat less wide than the right kidney. Each kidney lies obliquely with its long axis directed inferolaterally. Owing to this obliquity, the upper pole of the kidney is 2 cm closer to the midline than the lower pole. Each kidney presents anterior and posterior surfaces which are demarcated from each other by lateral and medial borders. The lateral and medial borders meet at the upper and lower poles of the kidney. The lateral border is smooth and uniformly rounded, while the medial border features a prominent indentation halfway down its length. Within the indentation is a vertical slit termed the renal hilum. The hilum leads into a relatively large cavity termed the renal sinus. The hilum transmits the renal vessels and the renal pelvis. The latter is a funnel-shaped chamber which continues distally as the ureter (Figures 1 and 3). On account of the lateral border of the kidney being located well back in the paravertebral gutter, the renal hilum actually faces anteromedially rather than directly medially. Consequently, the so-called anterior and posterior surfaces of the kidney are in truth anterolateral and posteromedial, respectively. A three-dimensional appreciation of this natural orientation of the kidney is of paramount importance when performing percutaneous, endoscopic renal procedures.

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In life the kidneys appear reddish brown and are enveloped in a smooth fibrous capsule.

The renal capsule is closely applied to the renal cortex and continues inwards through the lips of the renal hilum to line the renal sinus (Figure 3). In a healthy kidney the capsule can be readily stripped off the renal cortex. Outside the renal capsule is a layer of fat that surrounds the kidney completely and even extends into the renal sinus (Figures 2 and 3). This layer of fat is termed the perinephric fat. Surrounding the perinephric fat is the renal fascia (Figure 2).

## 2 (Figure 1)

Posteriorly the topographical relations of the two kidneys are practically identical. Thus each kidney surrounded by its fascial coverings lies on a muscular bed made up of psoas major medially, transversus abdominis laterally, quadratus lumborum posteriorly and the diaphragm superiorly. The upper pole of the kidney overlies those diaphragmatic fibres which arise from the medial and lateral arcuate ligaments. The subcostal neurovascular structures and the iliohypogastric and ilioinguinal nerves run obliquely, behind the kidney and in front of quadratus lumborum. Posterosuperior to the kidney and separated from the kidney by the diaphragm is the costodiaphragmatic pleural recess (Figure 2). Through this recess the kidney is related, posteriorly, to the 12$^{th}$ rib on the right side and to the 11$^{th}$ and 12$^{th}$ ribs on the left side. The hilum of the kidney overlies the ipsilateral psoas major (Figure 1).

The anterior topographical relations of the kidneys differ markedly between the right and left sides (Figure 1). On the right side the second part of the duodenum overlies the anterior surface of the kidney adjacent to the hilum. The lower lateral part of the anterior surface is overlapped by the hepatic flexure of the colon. Each of these structures lifts the peritoneum away from the anterior surface of the kidney. Related to the upper pole and adjoining the anterior surface of the kidney is the base of the right suprarenal gland. The superolateral part of the anterior surface is covered by peritoneum and is overlapped by the visceral surface of the right lobe of the liver. Between the two lies the hepatorenal pouch (pouch of Rutherford Morison) of peritoneal cavity.

On the left side the anterior relations are as follows (Figure 1). The splenic flexure of the colon overlies the inferolateral part of the anterior surface of the kidney. The hilum and adjacent anterior surface are overlapped by the body of the pancreas accompanied by the splenic vessels. The pancreas and the splenic flexure lift the peritoneum away from the anterior renal surface. Related to the upper pole and the medial border of the kidney down to the level of the hilum is the left suprarenal gland (Figures 1 and 7). The anterior surface of the upper third of the left kidney is covered in peritoneum and is related to the medial surface of the spleen and the posterior surface of the gastric fundus. The anterior aspect of the left kidney and most of the structures related to it lie immediately behind the lesser sac and thus constitute the stomach bed.

## 3 (Figures 3 and 4)

Together the kidneys receive more than 1 litre of blood per minute, amounting to more than 20% of the total cardiac output. Each kidney is normally supplied by a single renal artery. The

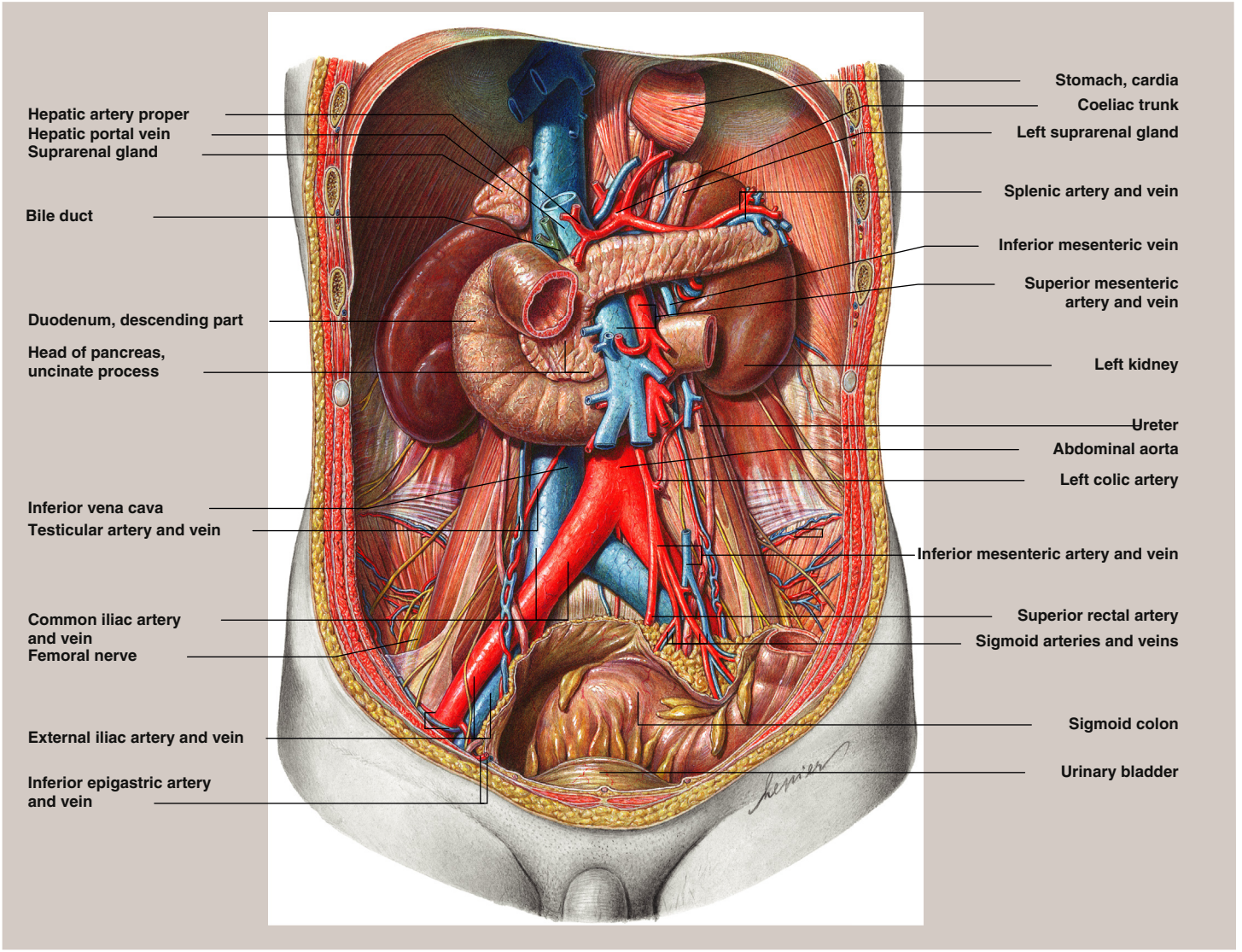


**Figure 1** The posterior abdominal wall and topographical relationships of the kidneys, ureters and suprarenals.

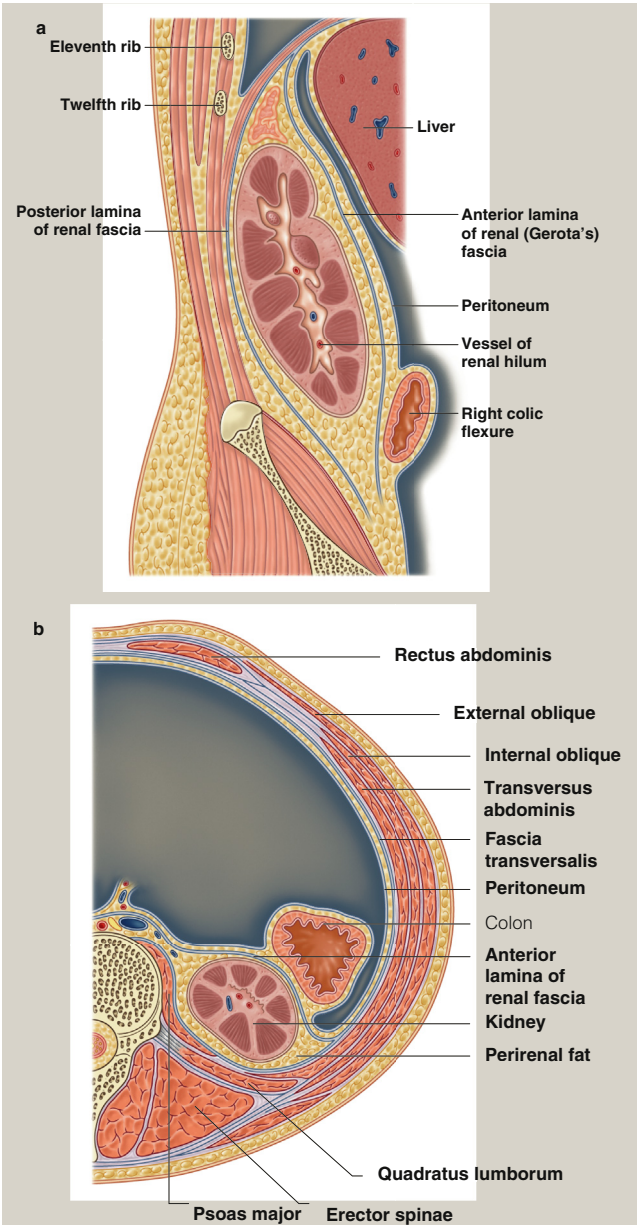


**Figure 2** Schematic sagittal and transverse sections of right kidney showing the renal fascia and its relationship to the peritoneum and posterior abdominal wall.

right and left renal arteries arise directly from the lateral aspect of the abdominal aorta, below the level of origin of the superior mesenteric artery. The right renal artery usually arises at a slightly higher level than the left renal artery. As it approaches the renal hilum each renal artery breaks up into an anterior division and a posterior division. On the basis of its blood supply, each kidney possesses five segments (Figure 4). The posterior division of the renal artery supplies the posterior segment while the anterior division divides into four segmental branches to supply the apical, upper, middle and lower segments.

Veins from the multiple renal segments communicate with each other freely unlike their arterial counterparts. Eventually the segmental veins join at the renal hilum to form the renal vein which runs medially to drain into the inferior vena cava. At the renal hilum the renal vein is the most anterior structure. Behind the renal vein runs the renal artery which in turn lies in front of the renal pelvis.

On viewing a coronal section of the kidney (Figure 3) it can be seen that occupying most of the renal sinus is the renal pelvis. As has already been noted the renal pelvis continues distally as the ureter. On tracing the renal pelvis proximally it is seen that the renal pelvis is formed by the confluence of two or three major calyces. Each major calyx, in turn, is formed by the confluence of a variable number of minor calyces. Each minor calyx surrounds a group of three or four renal papillae which discharge filtered urine into the minor calyces.

The ureter emerges from the hilum of the kidney and runs vertically downwards on the psoas fascia that covers the anterior surface of the psoas major muscle. Each ureter is a contractile, tubular conduit that connects the renal pelvis to the urinary bladder. The ureter lies retroperitoneally throughout its course. Its length in the adult is 25–30 cm. The wall of the ureter is made up of an inner mucosal layer lined in its entirety with transitional epithelium (urothelium) that is continuous proximally with the urothelium of the renal pelvicalyceal system and distally with the urothelial lining of the urinary bladder.

Outside the mucosal layer is the muscular coat of the ureteric wall featuring a meshwork of interweaving and interlacing smooth muscle fibres; an arrangement which enables the ureter to exhibit peristaltic movement. Outside the muscle coat is an adventitial layer containing a delicate network of blood vessels. The adventitial layer is adherent to the overlying posterior parietal peritoneum along the entire length of the ureter.

For descriptive convenience the ureter may be said to have two segments, of approximately equal length: (i) an abdominal segment that lies on the posterior abdominal wall and (ii) a pelvic segment that is located within the pelvic cavity. The pelvic brim is the arbitrary level of demarcation between the two segments.

The ureter features three natural constrictions: one at its upper end (the pelvi-ureteric junction), one where the ureter crosses the pelvic brim and one where the ureter adjoins the bladder lumen (vesico-ureteric junction). The last named is usually the narrowest part of the ureter and may have a luminal diameter, when undistended, of no more than 1 mm.

From its commencement at the pelvi-ureteric junction each ureter descends with a very slight medial inclination in front of the psoas fascia which covers the psoas major muscle. As it approaches the pelvic brim the ureter turns medially to leave the psoas major before crossing the pelvic brim anterior to, or just distal to, the bifurcation of the common iliac artery (Figure 1) level with the upper part of the sacroiliac joint to continue as the pelvic segment.

The pelvic segment of the ureter initially runs in a postero-lateral direction just inside the lateral wall of the pelvic cavity,

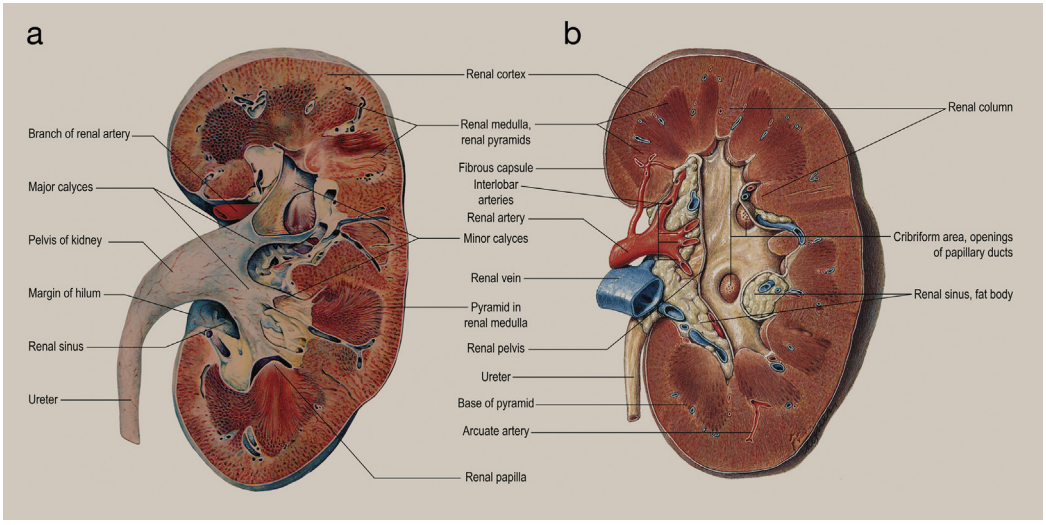


**Figure 3** Coronal sections through the left kidney showing pelvicalyceal system and renal sinus.

anterior to the internal iliac artery. On reaching the level of the ischial spine, the ureter turns to run anteromedially just above the pelvic floor before reaching the trigonal region on the posterior wall of the bladder.

**(Figure 1)**

The posterior topographical relations of the right and left ureters are very similar. The abdominal ureter descends in a more or less straight line on the anterior aspect of psoas major, the latter intervening between the ureter and the tips of the lumbar transverse processes. The genitofemoral nerve having emerged from the psoas major runs beneath the psoas fascia, behind the ureter. Lying behind the ureter at the pelvic brim is the common iliac artery and its bifurcation.

The anterior topographical relations of the ureter, however, differ between the right and left sides, and within the pelvic cavity they differ between the sexes (Figures 1 and 5).

Crossing anterior to the abdominal segment of the *right ureter* are the right colic vessels, ileocolic vessels, the right gonadal vessels and the lower end of the root of the small intestinal mesentery. Lying in front of the upper end of the right ureter is the second part of the duodenum.

Crossing anterior to the abdominal segment of the *left ureter* are the left colic vessels, left gonadal vessels, sigmoid vessels, and at the pelvic brim, the apex of the sigmoid mesocolon.

Great care must be taken to ensure the safety of the ureters during mobilization of the colon, whether it be for a right or left hemicolectomy.

Lying across the front of the upper end of the left ureter is the body of the pancreas (Figure 1).

Within the pelvic cavity of the male subject, posterolateral to the urinary bladder, the ureter is crossed anteriorly from lateral to medial by the vas deferens (Figure 5 a).

Posterolateral to the urinary bladder in the female subject, the ureter is crossed superiorly by the uterine artery (Figure 5 b).

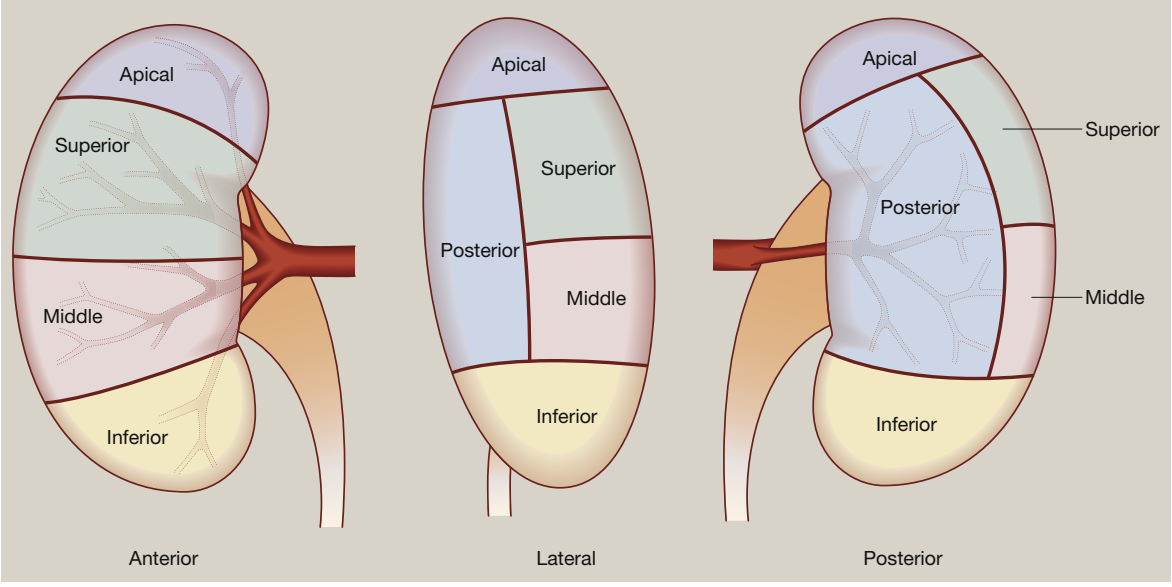


**Figure 4** Schematic representation of segmental arterial anatomy of right kidney.

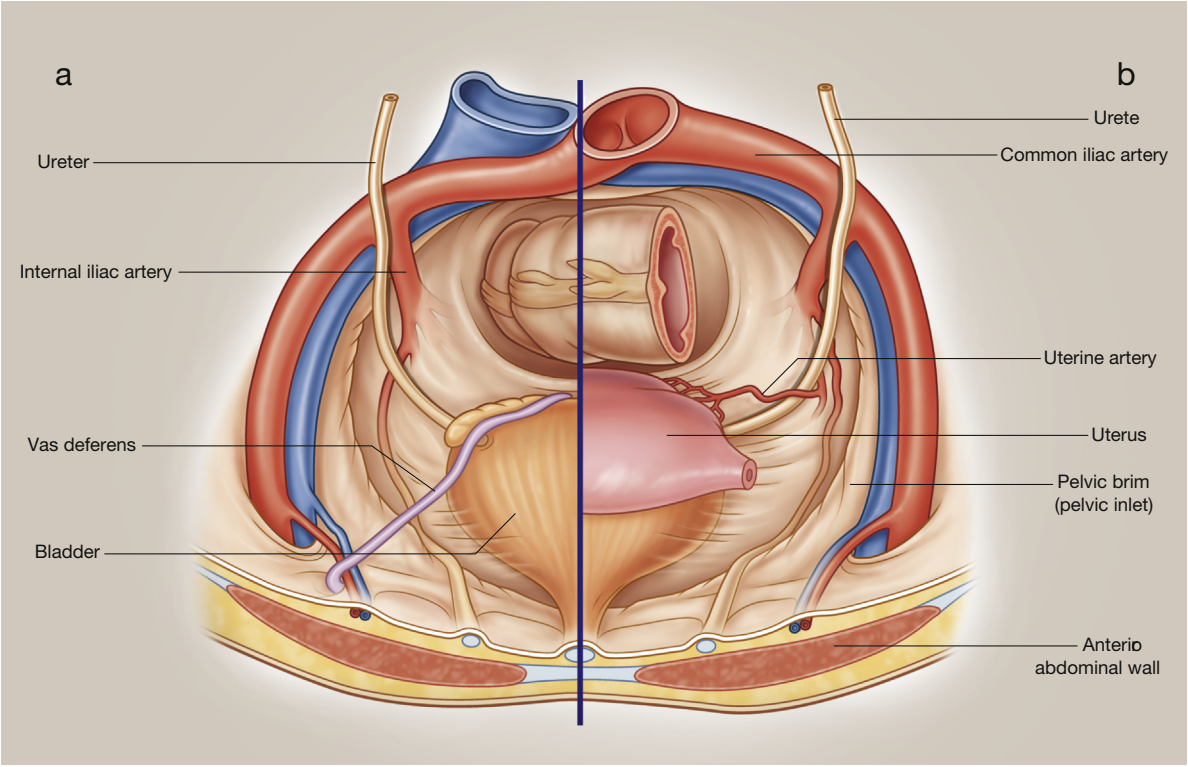


**Figure 5** Relations of intrapelvic ureter; a – male, b - female.

## (Figure 6)

The upper third of the ureter derives its blood supply from a ureteric branch of the ipsilateral renal artery. The middle third of the ureter receives a few small branches from the gonadal artery as the latter crosses the ureter. The common iliac and internal iliac arteries also often contribute to the blood supply of the middle third of the ureter. The intrapelvic segment of the ureter receives branches from the superior and inferior vesical branches of the internal iliac artery. The arteries from these various sources form a rich and delicate longitudinal anastomosis in the peri-ureteric adventitia. Extensive stripping of this adventitial covering during surgery may seriously compromise ureteric blood supply.

## (Figures 1 and 7)

The suprarenal glands, also known as adrenal glands, are two brownish yellow, compact and encapsulated structures, each closely related to the upper pole of the corresponding kidney. The kidney and suprarenal gland are surrounded by perinephric fat which, in turn, is enveloped in renal fascia. However, within this renal fascial envelope, a fibrous septum separates the suprarenal gland from the renal capsule. Thus it is possible to perform a partial or total nephrectomy without dislodging the suprarenal gland. Equally, an adrenalectomy may be performed without injuring the kidney.

The right and left suprarenal glands differ from each other in shape, and in their respective topographical relationships.

The right suprarenal gland is pyramidal in shape. Inferiorly it is related to the upper pole of the right kidney. Posteriorly it lies on the right crus of the diaphragm. Anteriorly it is overlapped by the inferior vena cava medially and by the bare area of the liver laterally.

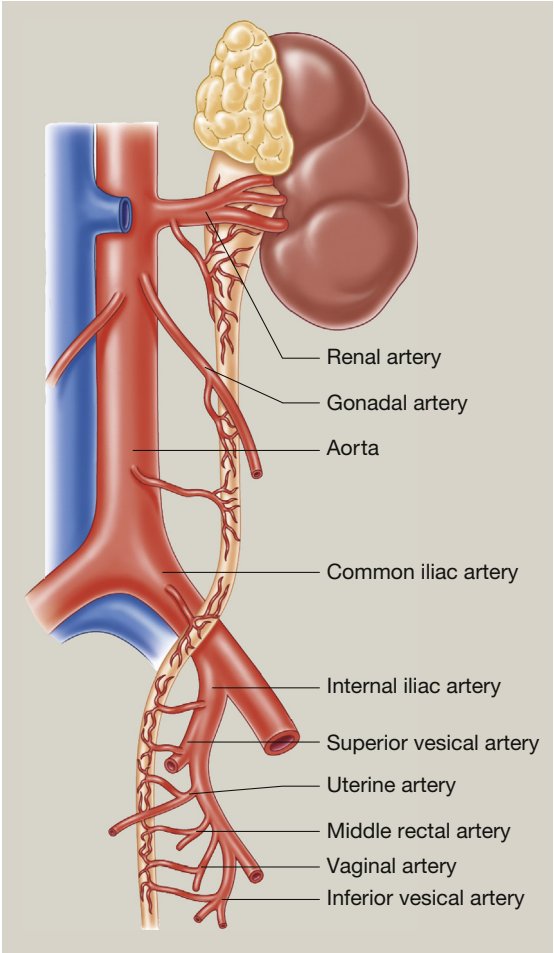


**Figure 6** Arterial supply of ureter.

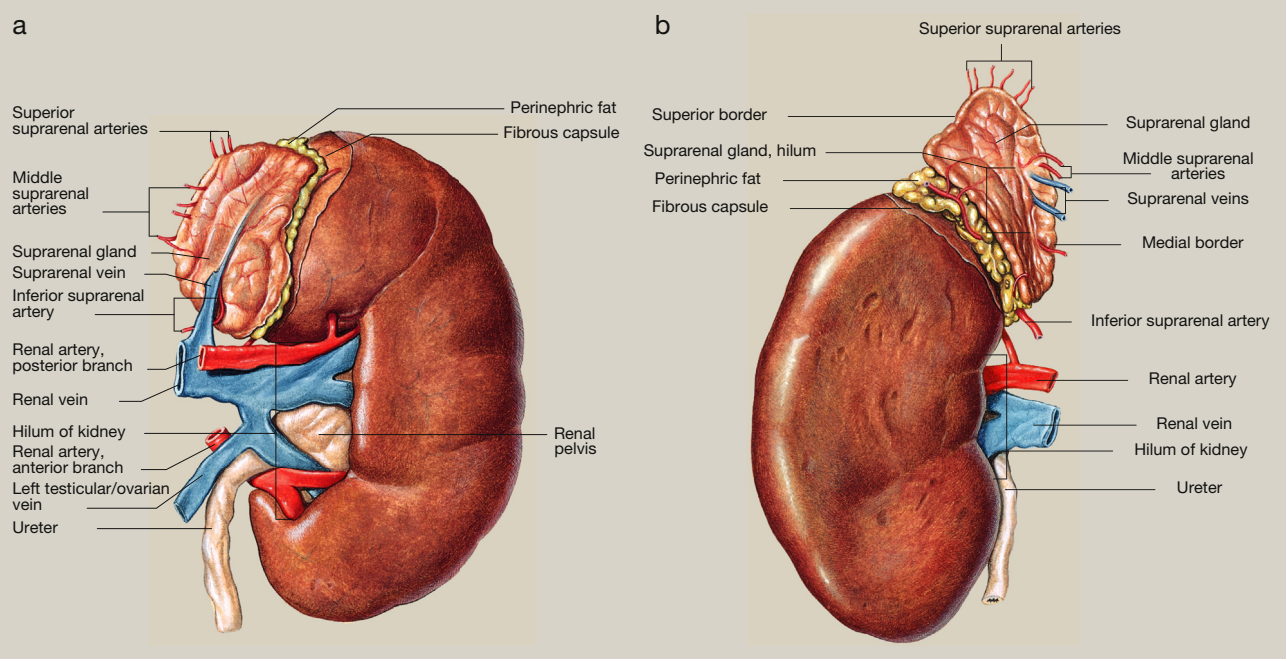


**Figure 7** Ventral view of right and left suprarenal glands and their blood supply.

The left suprarenal gland is somewhat semilunar in outline and its concave aspect is related to the upper pole and medial border of the left kidney down to the level of the renal hilum.

## (Figure 7)

In common with other endocrine glands, the suprarenal gland has a very rich arterial blood supply. This is derived from three arteries: (i) a suprarenal artery arising directly from the abdominal aorta, (ii) a suprarenal branch from the ipsilateral renal artery and (iii) a suprarenal branch from the ipsilateral inferior phrenic artery.

Notwithstanding the multiple arterial branches that supply the suprarenal gland, the venous drainage of the gland is usually by a single vein. The right suprarenal vein drains directly into the inferior vena cava while the left suprarenal vein drains into the left renal vein. ◆

## FURTHER READING

Ellis H, Mahadevan V, eds. Clinical anatomy. 14th edn. Wiley Blackwell, 2018.

Moore KL, Dalley AF, Agur AMR, eds. Clinically oriented anatomy. 7th edn. Wolters Kluwer/Lippincott Williams & Wilkins, 2014.