Renal pelvis and calyces are lined by transitional epithelium. 

Renal vasculature 

- Each kidney is supplied by the renal artery (branch of abdominal aorta) and is drained by the renal vein to the IVC. Renal artery divides into:
  a) Posterior division: Supplies posterior segment.
  b) Anterior division: Divides further into branches to supply apical, upper anterior, middle anterior and lateral segments.

- Thus, there are five vascular segments in each kidney: Posterior, apical, upper anterior, middle anterior and lateral.
- Branches of renal artery are end arteries.

Renal vein: Left renal vein is longer and passes in front of abdominal aorta, behind the origin of the superior mesenteric artery. Therefore, it may be compressed in the narrow angle between the renal arteries. Left renal vein also receives left inferior phrenic veins, left gonadal vein, and left suprarenal (adrenal) vein. Each renal vein begins beneath the true capsule as the stellate vein.

Nerve supply

- The kidney is supplied by the renal plexus, an offshoot of the coeliac plexus. It contains sympathetic (T₁₀₋L₁) fibers which are chiefly vasomotor. The afferent nerves of the kidney belong to segments T₁₀ to T₁₂.

Renal angle

- The angle between the lower border of the 12th rib and the outer border of the erector spinae (sacrospinalis) is known as renal angle. It overlies the lower part of the kidney. Tenderness in the kidney is elicited by applying pressure over this angle with thumb.

URETERS

- Ureters are a pair of thick walled tubes which convey urine from kidneys to the urinary bladder. It is a retroperitoneal structure. Each ureter is 25 cm (10 inches) long and divides into abdominal and pelvic parts. The ureter begins within the renal sinus as a funnel shaped dilated portion called renal pelvis. Gradually, it narrows till the lower end of the kidney where it becomes the ureter proper. Ureter emerges from the hilum and runs vertically downward retroperitoneally behind parietal peritoneum on the psoas muscle. It enters the true (lesser) pelvis by crossing anterior to the bifurcation of common iliac artery and origin of external iliac vessels. In front of sacroiliac (SI) joint. Opposite the ischial spine it turns anteromedially to reach the bladder base at an angle (not straight). Ureter opens into lateral angle of trigone. Ureteric openings lie 5 cm apart in distended bladder and only 2.5 cm apart in empty bladder.

- Ureter measures about 3 mm in diameter, but is constricted at five places: (i) pelviureteric junction (at the level of bifurcation of common iliac artery and crossing of external iliac artery); (ii) brim of lesser pelvis (at the level of bifurcation of common iliac artery and crossing of external iliac artery); (iii) point of crossing of ureter by ductus deferens or broad ligament; (iv) entry in bladder wall (this vesicoureteral junction is the narrowest part of ureter); and (v) opening in lateral angle of trigone.

Ureter is lined by transitional epithelium.

Important relations of abdominal part

- Relations of abdominal part of ureter are:-
  1) Anterior relations
     i) Right ureter: Duodenum (3rd part), peritoneum, right colic vessels, iliac vessels, root of the mesentery, and ileum (terminal part).
     ii) Left ureter: Peritoneum, gonadal artery, left colic vessels, sigmoid colon, and sigmoid mesocolon.

  2) Posterior relations
     a) Ureter lies on psoas major, transverse process (tips), and genitofemoral nerve.

  3) Medially
     i) Right ureter: IVC
     ii) Left ureter: Left gonadal vein and inferior mesenteric vein.

Important relations of pelvic part

- Relations of pelvic part of ureter are:-
  1) Posterior relations
     a) Posteriorly ureter is related to the internal iliac artery, initiation of anterior trunk of internal iliac artery, internal iliac vein, lumbosacral trunk and SI joint.
The renal vein
2. The renal artery, and
3. The renal pelvis, which is the expanded upper end of the ureter.

Examination of these structures enables the anterior and posterior aspects of the kidney to be distinguished from each other. As the pelvis is continuous inferiorly with the ureter, the superior and inferior poles of the kidney can also be distinguished by examining the hilum. So it is possible to determine the side to which a kidney belongs by examining the structures in the hilum. Commonly, one of the branches of the renal artery enters the hilus behind the renal pelvis, and a tributary of the renal vein may be found in the same plane.

RELATIONS OF THE KIDNEYS

The kidneys are retroperitoneal organs and are only partly covered by peritoneum anteriorly.

Relations Common to the Two Kidneys

1. The upper pole of each kidney is related to the corresponding suprarenal gland. The lower poles lie about 2.5 cm above the iliac crests.
2. The medial border of each kidney is related to:
   a. The suprarenal gland, above the hilus, and
   b. To the ureter below the hilus (Fig. 24.3).
3. Posterior relations: The posterior surfaces of both kidneys are related to the following.
   a. Diaphragm
   b. Medial and lateral arcuate ligaments
   c. Psoas major
   d. Quadratus lumborum
   e. Transversus abdominis
   f. Subcostal vessels; and
   g. Subcostal, iliohypogastric and ilioinguinal nerves (Fig. 24.4).

In addition, the right kidney is related to twelfth rib, and the left kidney to eleventh and twelfth ribs.
4. The structures related to the hilum have been described earlier.

Two Poles of the Kidney

The upper pole is broad and is in close contact with the corresponding suprarenal gland. The lower pole is pointed.

Two Surfaces

The anterior surface is said to be irregular and the posterior surface flat, but it is often difficult to recognize the anterior and posterior aspects of the kidney by looking at the surfaces. The proper way to do this is to examine the structures present in the hilum as described below.

Two Borders

The lateral border is convex. The medial border is concave. Its middle part shows a depression, the hilus or hilum.

Hilum

The following structures are seen in the hilum from anterior to posterior side.
Other Relations of the Right Kidney

**Anterior Relations**
1. Right suprarenal gland
2. Liver
3. Second part of duodenum
4. Hepatic flexure of colon
5. Small intestine.
   Out of these the hepatic and intestinal surfaces are covered by peritoneum.

The lateral border of the right kidney is related to the right lobe of the liver and to the hepatic flexure of the colon (Fig. 24.3).

Other Relations of the Left Kidney

**Anterior Relations**
1. Left suprarenal gland
2. Spleen
3. Stomach
4. Pancreas
5. Splenic vessels
6. Splenic flexure and descending colon

Out of these the gastric, splenic and jejunal surfaces are covered by peritoneum.

The lateral border of the left kidney is related to the spleen and to the descending colon.

**CAPSULES OR COVERINGS OF KIDNEY**

**The Fibrous Capsule**
This is a thin membrane which closely invests the kidney and lines the renal sinus. Normally it can be easily stripped off from the kidney, but in certain diseases it becomes adherent and cannot be stripped (Figs 24.5 and 24.6).

**Perirenal or Perinephric Fat**
This is a layer of adipose tissue lying outside the fibrous capsule. It is thickest at the borders of the kidney and fills up the extra space in the renal sinus.

Renal Fascia

The perirenal fascia was originally described as being made up of two separate layers.

- Posterior layer was called fascia of Zuckerkandall and anterior layer as fascia of Gerota.

These two fasciae fused laterally to form lateral conal fascia. According to this view, lateral conal fascia continued anterolaterally behind colon to blend with parietal peritoneum.

But lately it has been researched that the fascia is not made up of fused fasciae, but of a single multilaminated structure which is fused posteromedially with muscular fasciae of psoas major and quadratus lumborum muscles.

The fascia then extends anteromedially behind the kidney as bilaminated sheet, which divides at a variable point into thin layer which courses around the front of
kidney as anterior perirenal fascia and a thicker posterior layer which continues anterolaterally as the lateral conal fascia.

It was believed earlier that above the suprarenal gland the anterior and posterior perirenal fasciae fuse with each other and then get fused to the diaphragmatic fascia, but research presently demonstrates that superior aspect of perirenal space is "open" and is in continuity to the bare area of liver on the right side and with subphrenic extraperitoneal space on the left side.

On the right side at the level of upper pole of kidney, anterior fascia blends with inferior coronary layer and bare area of liver.

On the left side, anterior layer fuses with gastrophrenic ligament.

Posterior layer on both right and left sides fuses with fasciae of muscles of posterior abdominal wall, i.e. psoas major and quadratus lumborum as well as with fascia on the inferior aspect of thoracoabdominal diaphragm.

Medially the anterior layer is continuous from one to the other kidney and the posterior layer is attached either side of vertebral.

Below both the layer extend along the ureter and fuse with iliac fascia.

Pararenal or Perinephric Body (Fat)
It consists of a variable amount of fat lying outside the renal fascia. It is more abundant posteriorly and towards the lower pole of the kidney. It fills up the pararenal gutter and forms a cushion for the kidney.

Structure

Naked eye examination of a coronal section of the kidney shows:
1. An outer, reddish brown cortex.
2. An inner, pale medulla.
3. A space, the renal sinus (Fig. 24.7).

The renal medulla is made up of about 10 conical masses, called the renal pyramids. Their apices form the renal papillae which indent the minor calyces.

The renal cortex is divisible into two parts:
- a. Cortical arches or cortical lobules, which form caps over the bases of the pyramids.
- b. Renal columns, which dip in between the pyramids.

Each pyramid along with the overlying cortical arch forms a lobe of the kidney.

The renal sinus is a space that extends into the kidney from the hilus. It contains:
- b. Tributaries of the renal vein.
- c. The renal pelvis. The pelvis divides into 2 to 3 major calyces, and these in their turn divide into 7 to 13 minor calyces. Each minor calyx (calyx = cup of a flower) ends in an expansion which is indented by one to three renal papillae.

**Structure of Uriniferous Tubule**

Each kidney is composed of one to three million uriniferous tubules. Each tubule consists of two parts which are embryologically distinct from each other. These are as follows.

The excretory part, called the nephron, which elaborates urine. Nephron is the functional unit of the kidney, and comprises:

- a. Renal corpuscle or Malpighian corpuscle, (for filtration of substances from the plasma) made up of glomerulus (Latin ball) a tuft of capillaries and Bowman’s capsule (Fig. 24.8).
- b. Renal tubule, (for selective resorption of substances from the glomerular filtrate) made up of the proximal convoluted tubule, loop of Henle with its descending and ascending limbs, and the distal convoluted tubule (Fig. 24.8).

The collecting part begins as a junctional tubule from the distal convoluted tubule. Many tubules unite together to form the ducts of Bellini which open into the minor calyces through the renal papillae.

**Juxtaglomerular apparatus** is formed at the vascular pole of glomerulus which is intimately related to its own ascending limb of the Henle’s loop near the distal convoluted tubule. The apparatus consists of:

- a. Macula densa, formed by altered cells of the tubule.
- b. Juxtaglomerular cells, formed by the epithelial cells in the media of the afferent arteriole.
- c. Some agranular cells between macula densa and the glomerulus proper.

**Vascular Segments**

The renal artery gives 5 segmental branches, 4 from its anterior division and one from its posterior division (Fig. 24.9).
Blood Supply of Kidney

The blood supply of kidney shown in Flow chart 24.1 and Figs 24.7 and 24.10.

Lymphatic Drainage

The lymphatics of the kidney drain into the lateral aortic nodes located at the level of origin of the renal arteries (L2).

Nerve Supply

The kidney is supplied by the renal plexus, an off shoot of the coeliac plexus. It contains sympathetic (T10–L1) fibres which are chiefly vasomotor. The afferent nerves of the kidney belong to segments T10 to T12.

EXPOSURE OF THE KIDNEY FROM BEHIND

In exposing the kidney from behind, the following layers have to be reflected one by one (Fig. 24.11).

1 Skin
2 Superficial fascia
3 Posterior layer of thoracolumbar fascia with latissimus dorsi and serratus posterior inferior
4 Erector spinae, which can be removed for convenience
5 Middle layer of thoracolumbar fascia
6 Quadratus lumbarum
7 Anterior layer of thoracolumbar fascia in which the related nerves are embedded.
HISTOLOGY

The cortex of kidney shows cut sections of glomeruli, many sections of proximal convoluted tubule, some sections of distal convoluted tubule and few collecting ducts. Section through the pyramid of the medulla shows light staining collecting ducts, sections of loop of Henle, thick and thin segments of descending and ascending limbs, capillaries and connective tissue (Figs 24.12a and b).

In surgical exposures of the kidney, when sometimes the 12th rib is resected for easier delivery of the kidney, danger of opening the pleural cavity must be borne in mind. The lower border of the pleura lies in front of the 12th rib and behind the diaphragm. The order of structures from anterior to posterior side being diaphragm, pleura and rib. When the 12th rib is absent or is too short to be felt, the 11th rib may be mistaken for the 12th, and the chances of opening the pleural cavity are greatly increased (Fig. 24.13). Lithotripsy has replaced conventional method to some degree. The angle between the lower border of the 12th rib and the outer border of the erector spinae is known as the renal angle. It overlies the lower part of the kidney. Tenderness in the kidney is elicited by applying pressure over this angle, with the thumb (Fig. 24.14).
Blood from a ruptured kidney or pus in a perinephric abscess first distends the renal fascia, then forces its way within the renal fascia downwards into the pelvis. It cannot cross to the opposite side because of the fascial septum and midline attachment of the renal fascia.

Kidney is palpated bimanually, with one hand placed in front and the other hand behind the flank. When enlarged, the lower pole of kidney becomes palpable on deep inspiration (Fig. 24.15).

A floating kidney can move up and down within the renal fascia, but not from side to side.

In such condition the posterior layer of renal fascia can be sutured with diaphragm and kidney can be fixed in position.

The common diseases of kidney are nephritis, pyelonephritis, tuberculosis of kidney, renal stones and tumours.

Common manifestations of a kidney disease are renal oedema and hypertension. Raised blood urea indicates suppressed kidney function and renal failure. Kidney transplantation can be done in selected cases (Figs 24.16a and b).

One common congenital condition of kidney is polycystic kidney which leads to hypertension (Fig. 24.17).

In cases of chronic renal failure dialysis needs to be done. It can be done as peritoneal dialysis (Fig. 24.18) or haemodialysis (Fig. 24.19).

The kidneys are likely to be injured due to penetrating injuries to lower thoracic cage. These may also be injured by kicks in the renal angle—angle between the vertebral column and 12th rib.

Kidney is likely to have stones as urine gets concentrated here (Fig. 24.20a).

Kidney stone lies on the body of vertebra (Fig. 24.20b), Gallstones lie anterior to body of vertebra (Fig. 24.20c).

**URETERS**

The ureters are a pair of narrow, thick-walled muscular tubes which convey urine from the kidneys to the urinary bladder (Fig. 24.21).
Figs 24.31a to e: Development of excretory system of permanent kidney: (a) Metanephric cap, (b) renal vesicles, (c) S-shaped tubule, (d) Bowman’s capsule and glomerulus, and (e) differentiation and growth of parts of nephron, loop of Henle, proximal and distal convoluted tubules.

Figs 24.32a to e: Development of collecting system of permanent kidney: (a) Formation of ureteric buds, (b) capping of ureteric bud by metanephros, and (c to e) formation of ureter, renal pelvis, major calyces, minor calyces and collecting tubules.