Surgical anatomy of the kidney and ureters

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Abstract

This paper describes the anatomy of the kidney and ureter. It begins with the embryological development and the mechanism for some congenital anomalies. The microscopic anatomy is described; as well as the gross anatomy of the kidneys, ureters and suprarenal (adrenal) glands including anatomical relations, arterial supply and venous and lymphatic drainage. Nerve supply and pain are also discussed.

Keywords Anatomy; embryology; innervation; kidney; lymphatic drainage; ureters; vasculature

Position and function

The kidneys are paired solid organs (11 cm × 6 cm × 3 cm) usually situated within the retroperitoneum on either side of the spine.

They are responsible for:

- urinary excretion
- fluid, electrolyte and acid–base balance
- vitamin D metabolism
- renin and erythropoietin production.

Embryology

Three sets of structures appear and then regress in succession; the pronephros, the mesonephros and the metanephros – which persists to form the definitive kidney.

In the male the persistent longitudinal collecting duct of the mesonephros – the **mesonephric (or Wolffian) duct** forms; the duct of the epididymis, the vas deferens and the ejaculatory duct, the efferent ductules of the testis, the superior and inferior aberrant ductules and the appendix of the epididymis.

The **mesonephric duct** also gives rise to the ureteric bud in both sexes. Inferiorly this is absorbed into the bladder to become the trigone and part of the urethra, whilst superiorly it forms the ureter, the pelvis of the ureter, the major and minor calyces and the collecting ducts.

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The metanephros is initially a pelvic organ, from weeks 6 to 9 of gestation there is progressive development and the kidneys 'ascend' the posterior abdominal wall – secondary to the relative growth of the body in the lumbosacral regions and the straightening of its curvature. The ureter elongates as this 'ascent' occurs. The 'ascending' kidneys receive successive blood supply from lateral splanchnic arteries from the aorta until it reaches its final position opposite L2 vertebrae. Fusion of the lower poles of metanephric tissue results in a horseshoe kidney and alters the ascent and rotation of the developed kidneys.

Failure of development or interaction between the ureteric bud and metanephros have been implicated in congenital anomalies such as renal dysplasia and multicystic dysplastic kidneys.

Microscopic anatomy

The outer cortex appears lighter and the inner medulla darker. The medulla is composed of the renal pyramids, each with a rounded apex, which points centrally into the renal sinus where it is cupped by an individual minor calyx (a renal lobe). The renal cortex covers the pyramids peripherally and extends between the pyramids to the renal sinus (the columns of Bertin).

Gross anatomy

The gross anatomy of the kidney is shown in Figure 1. The renal capsule surrounds each kidney; it is a thin fibroelastic structure that encases the meat (parenchyma) and holds sutures whilst the parenchyma is very friable and will not. There is a depression (the hilum) on the medial surface of each kidney, which opens into the renal sinus – a central space surrounded by the renal parenchyma that contains the urinary collecting structures and renal vessels which exit the kidney via the hilum medially and varying amounts of fat.

The kidneys are mobile and their position changes during respiration. The right kidney generally lies lower than the left due to the mass of the liver. The upper pole of the left kidney lies at the level of the 12th thoracic vertebrae and its lower pole at the 3rd lumbar vertebrae. The upper pole of the right kidney lies at the level of the 1st lumbar vertebrae and its lower pole at the bottom of the 3rd lumbar vertebrae.

Posteriorly the diaphragm (and the pleural reflection) covers the upper pole/third of each kidney. The 12th rib crosses on both sides at the lower edge of the diaphragm. The upper border of the left kidney extends to the upper border of the 11th rib. Any direct approach to the upper pole of either kidney risks entering the pleural space and this should be minded with all supracostal approaches.

The medial portions of the lower two-thirds of both kidneys (with their associated renal vessels and pelvis) lie against the psoas muscle, whilst quadratus lumborum and the aponeurosis of transversus abdominus sit behind both kidneys.

Anatomical relations

The axis of each kidney is such that its lower pole lies farther from the midline and more anterior than its upper pole, causing the renal vessels and pelvis to exit the hilum in a relatively anterior direction. Anteriorly the right kidney lies behind the

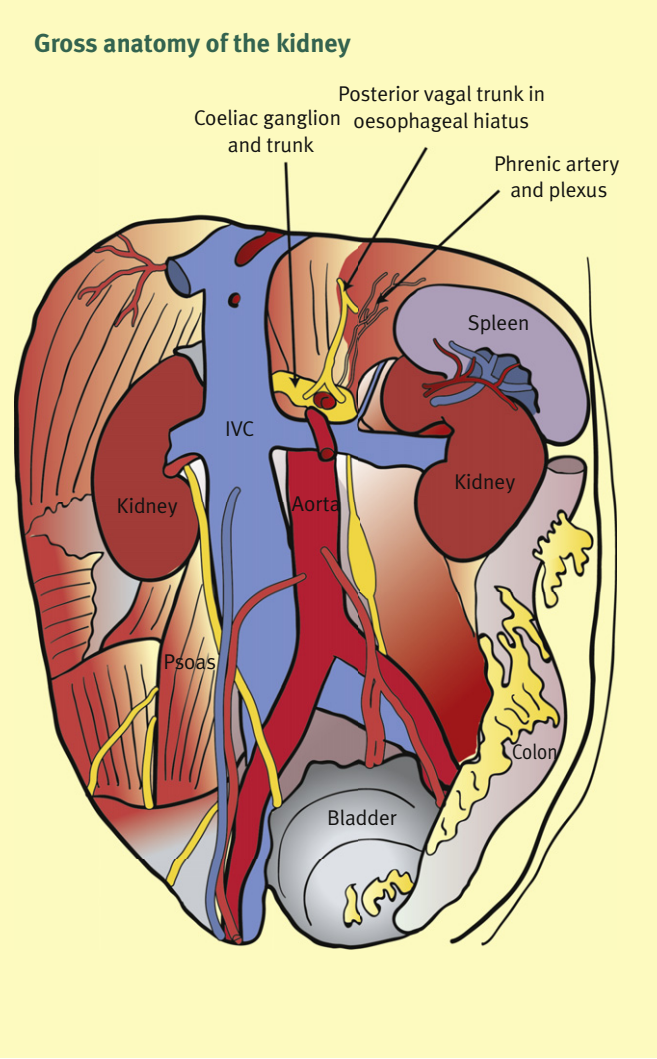

Figure 1

liver, separated from it by a reflection of peritoneum except for a small bare area of contact at the upper pole. This peritoneum forms the hepatorenal and the hepatocolic ligaments and excessive traction upon them during mobilization can produce hepatic tears. The duodenum is a direct medial relation of the right kidney and hilum; the hepatic flexure of the colon crosses its lower pole. See later section for the relationship to the adrenal glands.

The tail of the pancreas and the splenic vessels are anterior to the upper and middle portion and the hilum of the left kidney. Superiorly the left kidney is covered by the peritoneum of the lesser sac and the posterior gastric wall. Medially it is covered by the peritoneum of the great sac and the jejunum. The lower pole is crossed by the splenic flexure of the colon. Again the peritoneum in this region forms the splenorenal (linenorenal) and splenocolic ligament — traction upon which during operative mobilization can cause splenic bleeding.

Both kidneys and associated suprarenal glands are surrounded by perirenal fat and are loosely enclosed by the renal fascia — Gerota's fascia — which is an important anatomic and pathologic barrier. The anterior and posterior leaves of Gerota's fascia extend anterior and posterior to the kidney to fuse laterally, medially (where they extend across the midline and fuse densely to great vessels) and superiorly (where they fuse and disappear over the inferior diaphragmatic surface). Inferiorly they do not fuse and there remains an open potential space containing the ureter and gonadal vessels on either side which thins and is continuous with the retroperitoneal fascia.

Vasculature

The vascular pedicle composed of the posteriorly sited renal artery and more anteriorly sited renal vein enters the kidney via the renal hilum medially. The renal pelvis and ureter lie anterior to both in the hilum.

Arterial

The renal arteries leave the aorta at the level of the 2nd lumbar vertebral body. The right renal artery is longer than the left and travels posteroinferiorly behind the inferior vena cava to the lower right kidney. The shorter left artery passes horizontally and slightly posteriorly to reach the left kidney. The renal arteries provide small superior branches to the suprarenal glands and small inferior branches to the renal pelvis and upper ureter.

The main renal artery divides into five segmental arteries, one posterior and four anterior; posterior, apical, upper, middle and lower. The posterior branch exits before the hilum and supplies a large posterior segment whilst the remaining anterior branches are given off in the hilum. All five are end arteries, without anastomosis or collaterals. These segmental arteries pass through the renal sinus and branch into the lobar and then interlobar arteries.

Venous

The venous drainage mirrors the arteries — with interlobar and lobar veins uniting to become segmental veins. These in turn unite in the region of the sinus to become the renal veins. The right renal vein is shorter and drains in the inferior vena cava. The longer left renal vein receives the right gonadal and suprarenal veins (and in some cases the ascending lumbar vein) before passing anterior to the aorta to drain in the inferior vena cava.

Lymphatic

The principal lymph drainage for the left kidney is to the left paraaortic lymph nodes and on the right to the right interaortocaval and paracaval lymph nodes.

Suprarenal (adrenal) glands

Function

The adrenal glands are subdivided into a **medulla** that forms part of the sympathetic nervous system and secretes adrenaline (epinephrine) and noradrenaline (norepinephrine), and a **cortex** which secretes androgens and corticosteroids.

Microscopic anatomy

Each suprarenal gland is subdivided into two glands. They have a yellow external appearance with the mesodermal cortex enveloping the neural crest derived medulla.

Gross anatomy

These are paired glands situated superomedial to the kidneys — surrounded by perirenal fat and contained within Gerota's fascia. They are attached to the diaphragmatic crura. The right

suprarenal gland is tetrahedral and lies between the superior pole of the right kidney and the inferior vena cava and the left suprarenal gland is crescent shaped and lies on the superomedial border of the left kidney.

Vasculature

Arterial: the blood supply to both glands is from branches of the renal arteries, the inferior phrenic arteries and the aorta.

Venous: the left suprarenal vein drains into the left renal vein whilst the right suprarenal vein drains directly into the inferior vena cava.

Lymphatic: there are copious lymph vessels from the suprarenal glands — draining to the lumbar lymph nodes.

Ureters

Function

The ureters are paired hollow smooth muscular conduits for the active transport of urine into the bladder.

Microscopic anatomy

They are lined by transitional epithelium, outside this are two muscle layers (inner longitudinal and outer circular) continuous with that of the renal pelvis and calyces.

Gross anatomy

They descend bilaterally from the pelvi-ureteric junction in the retroperitoneum of the posterior abdominal wall on psoas major to the pelvic brim where they cross the bifurcation of the common iliac artery over the sacroiliac joint into the pelvis. In the pelvis the ureter runs over the external iliac artery and then continues down the pelvic sidewall anterior to the internal iliac artery. It turns anteriorly at the level of the ischial spine above the pelvic floor to enter the base of the bladder. In the male the ureter is crossed anteriorly by the vas deferens and in the female by the uterine artery.

There are three important narrowings of the ureteric lumen — at the pelvi-ureteric junction, crossing the iliac vessels and at the vesico-ureteric junction. Instrumentation and stones may get held up at these sites.

Vasculature

Arterial: for the proximal ureter is from the ureteric branch of the renal artery; the distal ureter gains its arterial supply from branches of the inferior and superior vesical arteries whilst the mid portion is supplied by an anastomosis of the gonadal artery with branches from the common iliac.

Venous: drainage follows arterial supply.

Lymphatic: upper — joins that of the kidneys or lumbar nodes, middle drains to the common iliac lymph nodes, the lower third drains to the common, internal or external iliac lymph nodes.

Nerve supply and pain

There is a sympathetic supply to the kidney from the 8th thoracic to 2nd lumbar nerves. The autonomic supply to the ureter is less clear. Pain signals travel with the sympathetic nerves leading to visceral pain (T8 to L2) distribution. This pain is referred along the genitofemoral nerve, ilioinguinal, iliohypogastric and subcostal nerves and explains the flank, groin and scrotal pain of ureteric colic. ◆

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