Anatomy of the kidney and ureter

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Abstract

A good understanding of the anatomy of the kidney and ureter is imperative while dealing with patients with abdominal trauma and those undergoing abdominopelvic surgery. The kidneys are situated in the retroperitoneum and are enveloped by the renal fascia. The renal fascia prevents the extravasation of blood during renal trauma. The lower poles of the kidneys are more prone to trauma as they are inferior to the 12th rib. However, due to the proximity of the kidneys to the lower ribs and pleura there is a risk of pleural injury during percutaneous renal interventions. Relative paucity of blood vessels in the posterolateral convex border of the kidney (Brodel's bloodless line) provides a relatively safe access to the pelvicalyceal system. The ureter has an abdominal and pelvic course and has three physiological narrowings: the uretero-pelvic junction, the point where the ureters cross the common iliac artery and the intra-vesical part of the ureter. These are the commonest sites for impacted calculi. The intra-vesical portion of the ureter is the narrowest portion of the ureter and this oblique intramural course helps in the formation of a functional sphincter that prevents vesico-ureteric reflux. The ureter is at risk of injury during colonic, vascular and gynaecological surgery.

Keywords Calyces; intravesical sphincter; kidney and ureter; renal hilum; renal surgery; ureteric calculi; ureteric injury

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Learning objectives

After reading this article you should understand the:
- clinical relevance of the anatomy of the kidney and ureter
- variations in the anatomy and their clinical implications
- potential complications to the kidney and ureter associated with abdomino-pelvic procedures

Kidneys

Introduction

The kidneys are a pair of highly vascular (receiving 20% of the cardiac output) solid organs located in the retroperitoneal space against the posterior abdominal wall between the transverse processes of T12-L3 vertebrae. The left kidney is positioned more superior than the right (due to presence of liver).

The kidneys perform multiple functions:
- filtration and excretion of metabolic waste products
- regulation and maintenance of fluid, electrolyte and acid—base balance
- regulation of blood pressure via the renin—angiotensin—aldosterone system
- stimulation of production of erythrocytes via secretion of erythropoietin
- calcium regulation via calcitriol production and vitamin D activation.

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Gross anatomy

Kidneys are bean-shaped organs each weighing between 130 and 150 g. Each kidney is about 10—12 cm long, 5—7 cm wide and 3—4 cm thick. The kidney is covered by a thin, glossy fibromuscular capsule which is surrounded by a protective layer of fat (peri-renal fat). Another layer of connective tissue termed **renal fascia** or **Gerota's fascia** encapsulates the kidney along with the perirenal fat and the adrenal gland. A second layer of **pararenal fat** lies external to the renal fascia.

Each kidney has two surfaces (anterior and posterior), two poles (upper and lower) and two borders (lateral and medial).

Anatomical relationships

Superiorly: Adrenal glands

Anteriorly: Liver, duodenum (second part), ascending colon and hepatic flexure on the right side and spleen, stomach, tail of the pancreas, descending colon and splenic flexure on the left side.

Posteriorly: Diaphragm, posterior recess of pleura, 12th rib, psoas and quadratus lumborum muscles, subcostal neurovascular bundle and nerves (ilioinguinal and iliohypogastric).

Laterally: Liver and ascending colon on the right and spleen and descending colon on the left.

Surface anatomy

The kidneys are positioned opposite the first four lumbar vertebrae in erect position. The hilum of each kidney is related to the transpyloric plane, left kidney lying just above and right just below this plane, about 5 cm from midline.

The kidney hilum and pedicle

The indented medial surface of kidney is called the hilum. Blood vessels, autonomic nerves and lymphatics enter and exit the kidney at the hilum. The hilum is also the point of emergence of the ureter from the kidney. Near the hilum, the ureter and renal vessels together form the pedicle within which the renal vein is anterior, ureter is posterior and renal artery more or less central. The hilum leads into a recess called the renal sinus that contains the pelvicalyceal system (see below) and the division of the blood vessels.

Arterial supply

The renal arteries arise perpendicularly from the lateral aspect of the abdominal aorta at L2 vertebral level and enter the kidneys through the renal hilum. The right renal artery passes behind the inferior vena cava (IVC) and is longer than the left.

The first branch of the **renal artery** is to the respective adrenal gland. It also gives branches to the renal pelvis and upper part of the ureter. Thereafter, the renal artery subdivides within the hilum into five **segmental arteries** that supply the kidney (corresponding to five segments of the kidney). The segmental arteries branch further into **interlobar arteries**. The latter run parallel to each other in between the major calyces and then subdivide into **arcuate arteries** that run within the cortex across the bases of the renal pyramids. The arcuate arteries extend into the cortex as **interlobular arteries**. These finally become **afferent arterioles** branching further into **glomerular capillaries** that rejoin to form **efferent arterioles**. There is a relative paucity of blood vessels in the posterior-lateral part of the kidney just behind the convex lateral border corresponding to the junction of the anterior and posterior divisions of the renal artery. This relatively avascular plane is called the Brodel's bloodless line or the 'avascular plane of Brodel'.

Venous drainage

Veins from all segments communicate extensively with each other unlike the arteries, which are end arteries. The efferent arterioles turn into a meshwork of peritubular capillaries that merge to form five or six veins that finally unite to form the large renal vein. Each renal vein drains the kidney in a similar fashion and joins the IVC. The left renal vein is longer than the right as it crosses the midline anterior to the aorta to reach the IVC. The left gonadal vein, left adrenal vein and lumbar veins drain into the left renal vein whereas on the right side the gonadal vein drains directly into the IVC.

Lymphatic drainage

The lymphatic drainage is similar to the venous drainage system. The ultimate drainage is into the para-aortic lymph nodes at L2 level.

Nerve supply

The kidney is supplied by autonomic nerves via the renal plexus that receives input from both the sympathetic and parasympathetic nervous system. The preganglionic sympathetic nervous innervation arising from T12-L1 spinal cord level stimulate vasoconstriction and consequent reduced blood flow. The vagus nerve contributes to the parasympathetic nerves that are responsible for vasodilatation in the kidney. Sensory input from the kidney travels to the T10-11 levels of the spinal cord and is sensed in the corresponding dermatomes in the flank and anterior abdominal wall.

The renal pelvis and the calyceal system

The renal pelvis is a funnel-shaped expansion of the upper end of the ureter.

It divides into two or three major calyces which further divide into eight to 12 minor calyces, each receiving a renal papilla (see below). The renal pelvis, through the ureteropelvic junction (UPJ) continues into the ureter.

Cross-sectional anatomy

Each kidney is composed of two layers: an outer paler and thinner layer — the cortex and an inner, darker layer — the medulla (Figure 1).

Renal cortex: the renal cortex is packed with distal convoluted tubules of nephrons. Here, groups of them merge together to form collecting ducts passing into the renal medulla (Figure 2). The collecting ducts combine into larger tubes called the papillary ducts. The renal cortex dips into the adjacent renal pyramids (below) to form renal columns of Bertin (Figures 1 and 2).

Renal medulla (pyramid): the renal medulla is composed of triangular masses of tissue called renal pyramids. Their bases are directed toward the convex surface of the kidney and apices of several of these pyramids open together into a renal papilla that bears the openings of collecting ducts. The renal papilla projects into a minor calyx (Figures 1 and 2).

Microscopic anatomy

The functional unit of the kidney is the nephron, each kidney having approximately 1 million of these.

The individual nephron consists of two major parts:

- The glomerulus: a tuft of capillaries arising from the afferent arteriole and ending into an efferent arteriole; the tuft is surrounded by the Bowman capsule that leads into the tubule system.
- Tubule system: the part adjacent to the Bowman capsule is called the proximal convoluted tubule (PCT). This leads into thin loop of Henle (LOH) with its ascending and descending limbs that in turn lead to the distal convoluted tubule and finally to the collecting tubule and collecting duct.

Applied anatomy

The position of the kidneys in the retroperitoneum makes them accessible to surgery through various routes (transabdominal, extraperitoneal flank approach and dorsal approach). Depending on which surgical approach is used the patient may need to be positioned either supine, prone or in the lateral position. Prior knowledge of the approach and positioning is therefore important to plan the anaesthetic course for the patient.

The lower ribs are closely related to the kidneys and may help protect the upper pole of the kidneys during trauma. Conversely, this proximity of the kidney to the lower ribs and pleura increases the risk of potential pleural/lung injury during surgery or percutaneous interventions of the kidney. However, as both kidneys extend below the 12th rib the lower poles are more susceptible to trauma or penetrating injuries in the costovertebral angle.

The avascular plane of Brodel located in the posterolateral convex border of the kidney provides relatively safe access to the pelvicalyceal system for procedures such as nephrostomy insertion or stone retrieval.

Congenital abnormalities

Agenesis (0.10%).

Persistence of fetal lobulations (6%).

