ANESTHETIC CONSIDERATIONS FOR RENAL TRANSPLANTATION

An essay submitted for partial fulfillment of the master degree in Anesthesiology

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Anatomy of the kidney

Topographic anatomy:

The kidneys are paired, reddish brown, solid organs situated on each side of the midline in the retroperitoneal space. Their weight depends on body size, averaging 150 g and 135 g in men and women respectively. Kidneys in adults vary in length from 11 cm to 14 cm, in width from 5 cm to 7 cm, and in thickness from 2.5 cm to 3 cm. Because of the effect of the hepatic position, the right kidney is shorter, broader, and lies 1 to 2 cm lower than the left kidney ***(Resnick et al., 2000).***

Anatomical relationships:

The upper pole of the left kidney lies at the level of T12, and the lower pole lies at the level of L3. The right kidney usually extends from the top of L1 to the lower end of L3. These relationships are changed with body position and respiration ***(EL-Galley and Keane, 2003).***

The kidneys and associated adrenal glands are surrounded by perirenal fat, which is enclosed in perinephric fascia which is known as Gerota fascia. The Gerota fascia forms an important anatomic barrier around the kidney and tends to contain pathologic processes originating from the kidney. In addition to the Gerota fascia, the vascular pedicle of the kidneys, the abdominal muscle tone, and the general bulk of the abdominal viscera support the kidneys ***(Resnick et al., 2000).***

The right adrenal gland covers the uppermost part of the anteromedial surface of the right kidney, The anterior relationships of the right kidney include the liver, which overlies the upper two thirds of the anterior two thirds of the anterior surface, and the hepatic flexure of the colon , which overlies the lower one third.

The right renal hilum is overlied by the second part of the duodenum. The anterior surface of the kidney beneath the liver is the only area covered by the peritoneum. The extension of the parietal peritoneum that bridges between the parietal fascia covering the upper pole of the right kidney and the posterior aspect of the liver is called the hepatorenal ligament.

The anteromedial surface of the left kidney is also covered by the left adrenal gland in the uppermost part. The spleen, body of the pancreas, stomach, and splenic flexure of the colon are all in an anterior relationship to the left kidney ***(Sampaio and Aragao, 2002).***

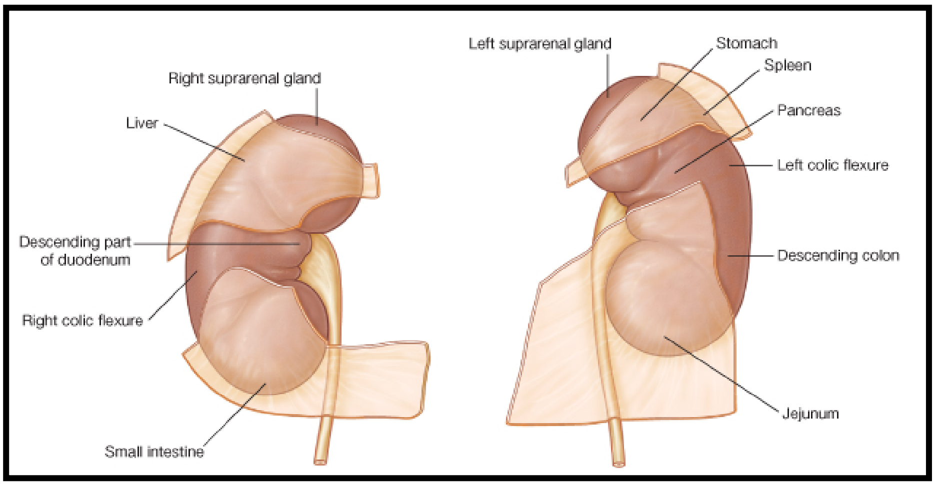

Figure 1: Relations of the kidney ***(EL-Galley and Keane, 2003).***

The area of the kidney beneath the small intestine, spleen, and stomach is covered by the peritoneum. The peritoneal extension between the perirenal fascia covering the upper pole of the left kidney and inferior splenic capsule is called the splenorenal or lienorenal ligament which is avascular.

Although the adrenal glands arise in an intimate anatomic relationship to the kidney, their separate embryologic origin means that their development is generally unaffected by common renal anomalies. The adrenal glands are fixed superiorly to Gerota's fascia, but they can be easily separated from the kidneys in surgery ***(Resnick et al., 2000).***

Both kidneys share relatively symmetric relationship to the posterior abdominal wall. the upper third or upper pole of each kidney lies on the diaphragm, behind which is the pleural reflection. An operative approach to this area with a high incision above the 11^{th} or 10^{th} rib risks entering the pleural space. The upper border of the left kidney usually extends to the upper border of the 11^{th} rib, whereas the upper pole of the right kidney, which is lower, is usually at the level of the 11^{th} intercostal space.

The lower two thirds of the posterior surface of both kidneys lie on three muscles, which from medial to lateral are the psoas major, quadratus lamborum, and aponeurosis of the transversus abdominis muscles. The renal vessels and pelvis lie against the contour of the psoas muscle, which tilts the lower pole of each kidney away from the midline (Figure 1) ***(EL-Galley and Keane, 2003).***

Renal parenchyma:

The renal parenchyma is divided into an internal dark medulla and an external, lighter cortex. The medulla is composed of 8 to 18 conic structures called the renal pyramids, which are made of ascending and descending loops of Henel and collecting ducts.

The round tip of each pyramid is known as the renal papilla. These papillae cannot be seen during surgical dissection because each papillary projection is encompassed by a smooth muscular sleeve called a minor calyx. These minor calyces coalesce to form two or three major calyces, which in turn join to form the renal pelvis. The renal pelvis extends through the renal hilum behind the renal vessels and continues as the ureter. Anatomic variations in the renal pelvis are not uncommon. The renal pelvis, which is usually partially extrarenal, may lie completely extarenal or intrarenal. In some cases, the renal pelvis may be duplicated, with duplication of the renal units, when this variation exists, it tends to occur bilaterally ***(Sampaio and Aragao, 2002).***

The renal cortex lies between the bases of the pyramids and the renal capsule. The tongues of cortical tissue, which extend between the renal pyramids, are called Bertin'scolumns. The outer border of the renal cortex is typically smooth ***(Resnick et al., 2000).***

Renal blood supply:

- **Arterial supply:**

Each kidney is classically supplied by a renal artery and a larger renal vein arising from the aorta and the inferior vena cava, respectively, at the level of L2, below the takeoff of the superior mesenteric artery. They enter the renal hilum medially, with the vein anterior to the artery and both anterior to the renal pelvis. Although the right kidney is in a lower position than is the left kidney, the right renal artery arises from the aorta at a higher level and takes a longer course than does the left renal artery. It must travel downward behind the inferior vena cava to reach the right kidney, whereas the left renal artery passes slightly upward to reach the left kidney. Because of the posterior position of the kidneys, both renal arteries course in a slightly posterior direction ***(Sampaio and Aragao, 2002).***

Two small but important branches arise from the main renal artery before its termination in the hilum. Ligation of this branch may result in ischemia to the area of the upper ureter with stricture formation. The main renal artery divides into five segmental arteries at the renal hilum. Each segmental artery is an end artery, so occlusion leads to ischemia and infarction of the corresponding renal segment. The first branch is the posterior artery, which arises just before the renal hilum and passes posterior to the renal pelvis to supply a large posterior segment of the kidney. The main renal artery then terminates into four anterior segmental arteries at the renal hilum. They are the apical, upper, middle, and lower anterior segmental arteries. The apical and inferior arteries supply the anterior and posterior surfaces of the upper and lower poles of the kidneys, respectively. The upper and middle arteries supply the two corresponding segments on the anterior surface of the kidney ***(EL-Galley and Keane, 2003).***

The segmental arteries course through the renal sinus and branch into the lobar arteries, which are usually distributed one for each pyramid. Each lobar artery divides into two or three interlobar arteries that pass between the renal pyramids to the corticomedullary junction, where they become the arcuate artery. The arcuate arteries, as their name implies, arch over the bases of the pyramids and give rise to a series of interlobular arteries, which in turn take a straight course to the renal cortex, with some terminal small branches anastomosing with the capsular arteries. This anastomosis can enlarge to supply a significant amount of blood to the superficial cortical glomeruli, especially in cases of gradual narrowing of the renal arteries ***(Resnick et al., 2000).***

Of importance to urologists is the relatively avascular plane on the posterior surface kidney, located approximately one third of the distance between the posterior and anterior surfaces. Incision through this line towards the renal pelvis is unlikely to traverse any major vessels. Similarly, transverse incisions are usually possible between the posterior segmental circulation and polar segments supplied by the apical or lower segmental arteries of the anterior circulation to gain access to upper or lower pole calyces (Figure 2) ***(Sampaio and Aragao, 2002).***

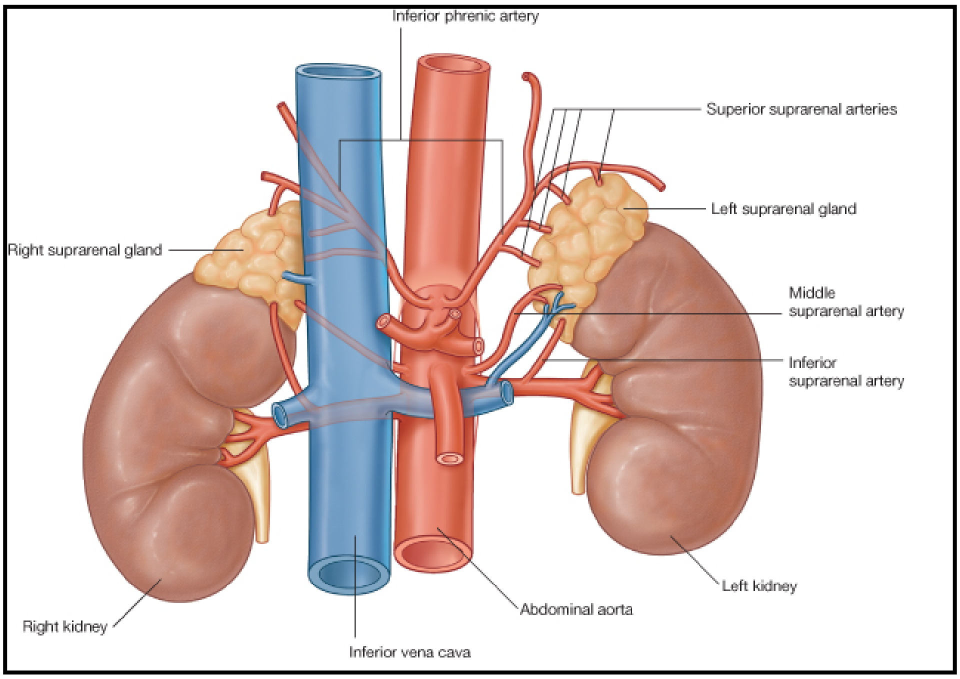

Figure 2: Blood supply of the kidney ***(Sampaio and Aragao, 2002).***

• Venous drainage:

The renal cortex is drained by the interlobular veins, which, unlike the renal arteries, anastomose freely with the arcuate veins at the base of the medullary pyramids and the capsular and perirenal veins on the surface of the kidney. The arcuate veins drain by the interlobar veins to the lobar veins, which join to form the renal vein. The right renal vein, 2 to 4 cm in length, joins the lateral aspect of the inferior vena cava, usually without receiving any tributaries. The left renal vein is 6 to 10 cm in length, crosses anterior to the aorta, and ends in the left aspect of the inferior vena cava. It receives three tributaries lateral to the aorta:

- The left adrenal vein superiorly.
- The left gonadal vein inferiorly.
- A lumber vein posteriorly.

At the renal hilum, the renal vein usually lies in front of the renal artery, but passing more medially, the renal artery may be 1 cm or more higher or lower than the vein ***(Resnick et al., 2000).***

Renal lymphatics:

Lymphatic vessels within the renal parenchyma consist of cortical and medullary plexuses, which follow the renal vessels to the renal sinus and form several large lymphatic trunks. The renal sinus is the site of numerous communications between lymphatics from the perirenal tissues, renal pelvis, and upper ureter. Initial lymphatic drainage runs to the nodes present at the renal hilum lying close to the renal vein. These nodes form the first station for lymphatic spread of renal cancer. On the left side, lymphatic trunks from the renal hilum drain to the para-aortic lymph nodes from the level of the inferior mesenteric artery to the diaphragm. Lymphatics from the right kidney drain into the lateral paracaval and interaortocaval nodes from the level of the common iliac vessels to the diaphragm. Lymphatics from both sides may extend above the diaphragm to the retrocrural nodes or directly into the thoracic duct ***(EL-Galley and Keane, 2003*****).**

Nerve supply:

The kidneys have both sympathetic and parasympathetic innervation, but the function of these nerves is poorly understood. Sympathetic fibers derived from the greater and lesser splanchnic nerves, link the celiac and superior mesenteric ganglion. Sympathetic and parasympathetic fibers travel around the renal artery to the renal pelvis ***(Resnick et al., 2000).***

Anatomy of the ureter

Topographic anatomy:

The ureter is a muscular tube that follows a gentle S-shaped course in the retroperitoneum. The muscle fibers are arranged in three separate layers:

- inner
- outer longitudinal
- middle circular

The length of the ureter in adults ranges from 28 cm to 34 cm, varying in direct relationship with the height of the individual. The average diameter of the ureter is 10 mm in the abdomen and 5 mm in the pelvis, but three areas of physiologic narrowing in the ureter should not be considered abnormal unless the proximal ureter is significantly dilated. These areas are located at the:

- ureteropelvic junction.
- point where the ureter crosses the iliac vessels.
- ureterovesical junction.

Anatomic relationship:

Both ureters have the same posterior relationship lying on the medial aspect of the psoas major muscle and traveling downwards, adjacent to the transverse processes of the lumbar vertebrae. They enter the pelvis medial to the sacroiliac joints, cross over the bifurcation of the common iliac vessels, and follow the hypogastric artery in a gentle lateral curve on the pelvic wall. At the level of the greater sciatic foramen, they turn medially again to enter the bladder obliquely and course submucosally for 2 cm to 3 cm, ending in the ureteral orifices ***(Resnick et al., 2000).***

Just proximal to their mid points, both ureters cross behind the gonadal vessels. The right ureter passes behind the second part of the duodenum, lateral to the inferior vena cava, and is crossed by the right colic and ileocolic vessels. The left ureter passes behind the left colic vessels, descend parallel to the aorta, and passes under the pelvic mesocolon ***(EL-Galley and Keane, 2003).***

In male patients, the ureter crosses under the vas deferens in close proximity to the upper end of the seminal vesicle before entering the urinary bladder. In female patients, the pelvic relationships are somewhat different. The ureter travels in the posterior border of the ovarian fossa and passes forward under the lower part of the broad ligament, lateral to the cervix, and under the uterine artery ***(Tanagho, 2002).***

Arterial blood supply:

The upper ureter derives its blood supply from a ureteric branch of the renal artery. During their course in the abdomen, the ureters receive blood from the gonadal vessels, aorta, and retroperitoneal vessels. In the pelvis, they receive additional branches from the hypogastric artery, vasal artery, and vesical arteries. The abdominal portion of the ureter has a medial vascular supply, whereas the pelvic part receives its blood vessels from the lateral side. This should be taken into consideration during partial mobilization of the ureter to preserve as much of the blood supply as possible ***(Sampaio and Aragao, 2002).***

Venous and lymphatic drainage:

The venous drainage of the ureter is paired with the arteries. Lymphatics from the renal pelvis and upper ureter drain into the lumbar lymph nodes. Lymphatic drainage from the middle ureter follows the internal iliac (hypogastric) and common iliac lymph nodes. The lower ureteral lymphatics empty into the vesical and hypogastric lymph nodes ***(EL-Galley and Keane, 2003).***

Nerve supply:

The ureteric muscle fibers contain alpha-adrenergic (excitatory) and beta-adrenergic (inhibitory) receptors, but peristaltic contractions occur in denervated ureters and can be altered by sympathomimetic or sympatholytic medications, which indicates that the role of nerve supply to the ureter is to modulate peristaltic activity rather than to initiate it ***(Resnick et al., 2000).***

Pathophysiologic effects of chronic renal failure

Definition and causes of chronic renal failure:

Chronic renal failure is defined as either kidney damage or a decreased kidney glomerular filtration rate (GFR) of less than 60 mL/min/1.73 m^2 for 3 or more months. Whatever the underlying etiology, the destruction of renal mass with irreversible sclerosis and loss of nephrons leads to a progressive decline in GFR ***(Salden, 2000)***.

The most common causes of chronic renal failure are related to:

- poorly controlled diabetes,
- poorly controlled high blood pressure, and
- chronic glomerulonephritis.

Less common causes of chronic renal failure include:

- polycystic kidney disease,
- reflux nephropathy,
- kidney stones, and
- prostate disease.

Diagnosis of chronic renal disease (CRD):

The symptoms of worsening kidney function are unspecific, and might include feeling generally unwell and experiencing a reduced appetite. Higher levels of creatinine indicate a falling glomerular filtration rate and as a result a decreased capability of the kidneys to excrete waste products. Creatinine levels may be normal in the early stages of CRD, and the condition is discovered if urinalysis (testing of a urine sample) shows that the kidney is allowing the loss of protein or red blood cells into the urine. CRD can also be diagnosed by screening of people known to be at risk of kidney problems, such as those with high blood pressure or diabetes and those with a blood relative with chronic renal disease. Chronic renal disease may also be identified when it leads to one of its recognized complications, such as cardiovascular disease, anemia or pericarditis ***(Belani and Palahniuk, 2003)***.

Pathophysiology of chronic renal failure:

The main functions of the kidney are:

- Excretion of waste products, water soluble toxic substances and drugs.
- Regulation of fluid balance and blood pressure (production of renin).
- Maintenance of acid-base balance.
- Reabsorption of glucose, amino acids, and other small molecules.
- Regulation of sodium, potassium, and other electrolytes.
- Production of various hormones including erythropoietin and vitamin D_3 ***(Linke, 2000).***

Chronic renal disease is initially without specific symptoms and can only be detected as an increase in serum creatinine or protein in the urine.