INTRODUCTION

The incidence of urinary stone disease has been increased due to the change in dietary habits, lifestyle factors and obesity ***(Oğuz et al., 2014).***

The prevalence of urinary stone disease was reported as 11.1% in the adult population, while the prevalence in children varies with age, it is approximately 2-3% ***(Erbagci et al., 2003).***

Malnutrition, racial factors, and anatomical and metabolic abnormalities are the most important risk factors responsible for the high incidence and recurrence rates in children. About 40-50 % of children with urolithiasis have a metabolic abnormality such as hypercalciuria, hyperoxaluria, hypocitraturia, cystinuria, or hyperuricosuria, with hypercalciuria and hypocitraturia ***(Sarica et al., 2006).***

Children with systemic disease need full metabolic and systemic evaluation. Paediatric patients have a high risk of recurrence because of long life expectancy and so, minimally invasive treatment options are preferred ***(Muslumanoglu et al., 2011).***

Open surgery was the only surgical treatment option in the past, The current treatment recommendations for kidney stones in children are similar to those in adults. For kidney stones <2 cm, extracoporeal shock wave lithotripsy (ESWL) has been recommended as the first-line treatment ***(McAdams et al., 2010).***

Now, most pediatric urinary stones can be treated effectively by minimally invasive modalities added to (ESWL) as percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS) ***(Tekgül et al., 2015).***

There are various factors affecting the stone-free rates of ESWL such as stone size, composition, and location. European Association of Urology (EAU) guidelines recommend ESWL as a first-line treatment option in children with upper ureter or renal pelvic stones <2 cm ***(Tekgül, 2011).***

Increase of the stone size results in a decrease of the stone-free rates and an increase of retreatment rates. The main disadvantage of ESWL in children is the need for anaesthesia. ***(Erbagci et al., 2003).***

However, PCNL has a significant role in cases of large and/or ESWL resistant stones. According to the EAU guidelines, PCNL is recommended as a primary treatment option for large renal stones (> 20 mm) ***(Tekgül et al., 2015).***

There are many factors affecting the success rate of PCNL, such as the anatomy of the kidneys, stone burden, and localization. The stone-free rate of PCNL is between 73-96% ***(Kapoor et al., 2008).***

Although the success rate with PCNL is nearly similar between children and adults. Small kidneys and large instruments make this surgery difficult in children. Children have less tolerance for bleeding, and this lack of tolerance can cause an anxiety for surgeons when performing PCNL.

The effect of tract dilatation on growing kidneys and the side-effects of radiation are also important points that must be defined. But there are insufficient data and few articles regarding the effect of PCNL on growing kidneys in the international literature ***(Moskovitz et al., 2006).***

Dawaba et al. reported that PCNL is a safe and effective procedure for the treatment of children with renal stones. At long-term follow up , the procedure improves renal function without renal scarring ***(Dawaba et al. , 2004)***

AIM OF THE STUDY

To assess the safety and efficacy of percutaneous nephrolithotomy in the treatment of renal stones more than 15 mm in children aged 2-14 years old.

Chapter 1

RENAL ANATOMY

Renal anatomy will include endourologic considerations, anatomy and kidney relationships as applied to minimally invasive surgery.

Understanding of the renal and perirenal anatomy during PCNL is important and necessary for effective and safe access and to avoid complications ***(Wolf et al., 2012).***

Grossly the kidneys are paired organs that rest in the retroperitoneum on the posterior abdominal wall. Each kidney is of a characteristic shape, having a superior and inferior pole, a convex border placed laterally, and a concave medial border. The medial border has a marked depression, the hilum, which contains the renal vessels and the renal pelvis (fig.1) ***(Smith, 2012).***

Because of compression by the liver, the right kidney tends to be somewhat shorter and wider ***(Anderson et al., 2012).***

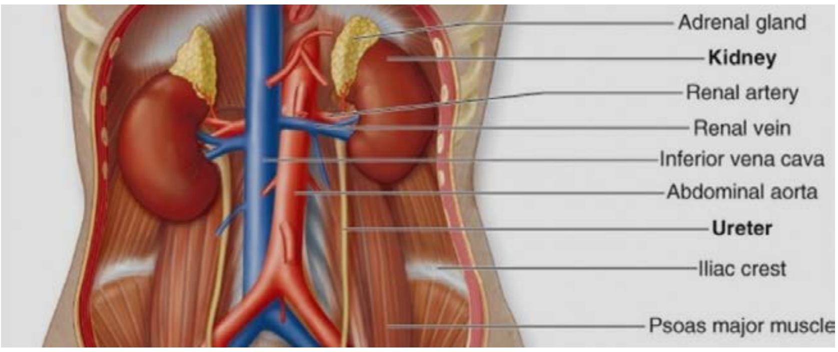

Fig. (1): Gross anatomy of the kidney ***(Smith, 2012).***

Position of the kidneys:

The kidneys lie adjacent to the vertebral bodies, usually extending from the 11 th or 12 th thoracic to the 2nd or 3rd lumbar vertebrae and they are protected by the 11th and 12th ribs (Fig. 2). The right kidney is displaced by compression by the liver a few centimeters inferior to the left kidney ***(Wolf et al., 2012).***

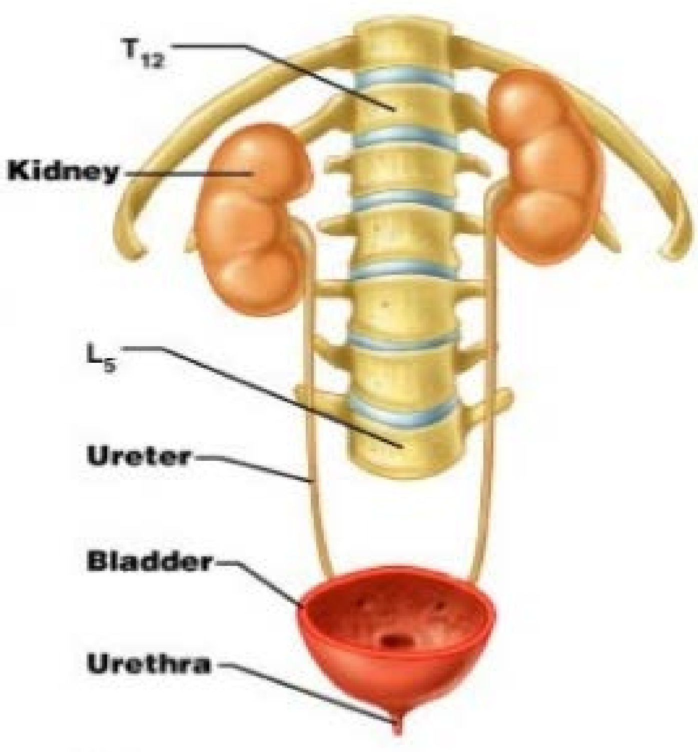

Fig. (2): Position of the kidneys in the retroperitoneum ***(Wolf et al., 2012).***

Kidney orientation

The main axis of kidneys is directed downwards, laterally, and anteriorly parallel to the oblique course of the psoas major muscles, with the superior poles closer to each other, more medial and more posterior than the inferior ones (Fig.3) Kidneys are angled 30°–50° behind the frontal coronal plane and their hilar region is rotated anteriorly with the lateral border rotated posteriorly (Fig.4). The supine or prone positions of the patient have no effect on the orientation of the kidneys ***(Aga and Bansal, 2010).***

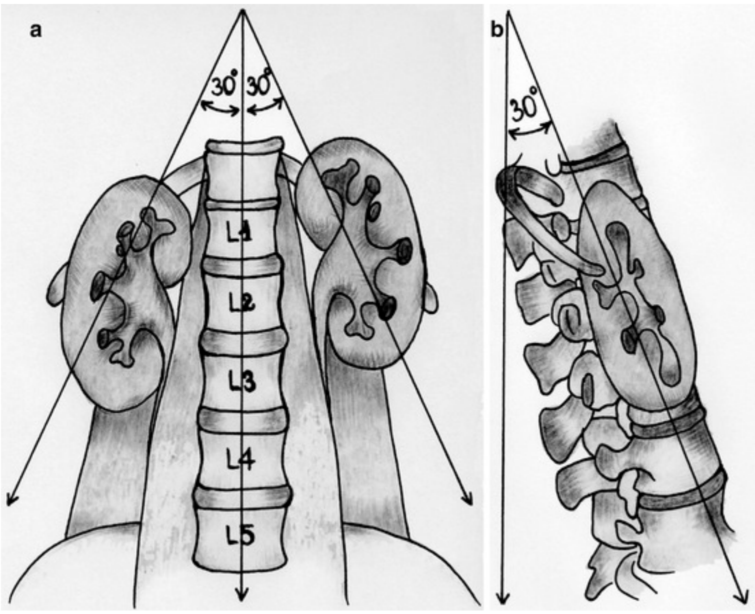

Fig. (3): Kidney orientation on the frontal plane (a) and on the sagittal plane (b) ***(Scoffone et al., 2014).***

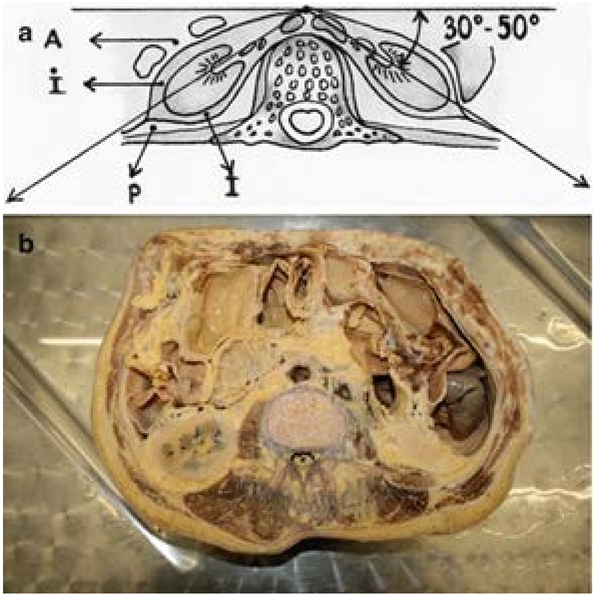

Fig. (4): (a) Kidney orientation on the coronal plane, (P posterior pararenal space, I intermediate perirenal space, A anterior pararenal space). (b) A picture from a coronal macrosection from a formalin-fixed cadaver ***(Scoffone et al., 2014).***

Perirenal Coverings:

The kidney surface is surrounded by 4 coverings as the following:

1. **Fibrous capsule**: which is closely adherent to the kidney surface.
2. **Perirenal fat**: which is a mass of adipose tissue, lies between the peritoneum and the posterior abdominal wall and covers the fibrous capsule.
3. **Renal fascia (Gerota's fascia)**: A condensation of areolar connective tissue that lies outside the perirenal fat and encloses the kidney and the suprarenal gland.

4. **Pararenal fat**: Lies external to the renal fascia, is part of the retroperitoneal fat. The last 3 structures support the kidneys and hold it in position on the posterior abdominal wall ***(Fig. 5) (Elspeth et al., 2002).***

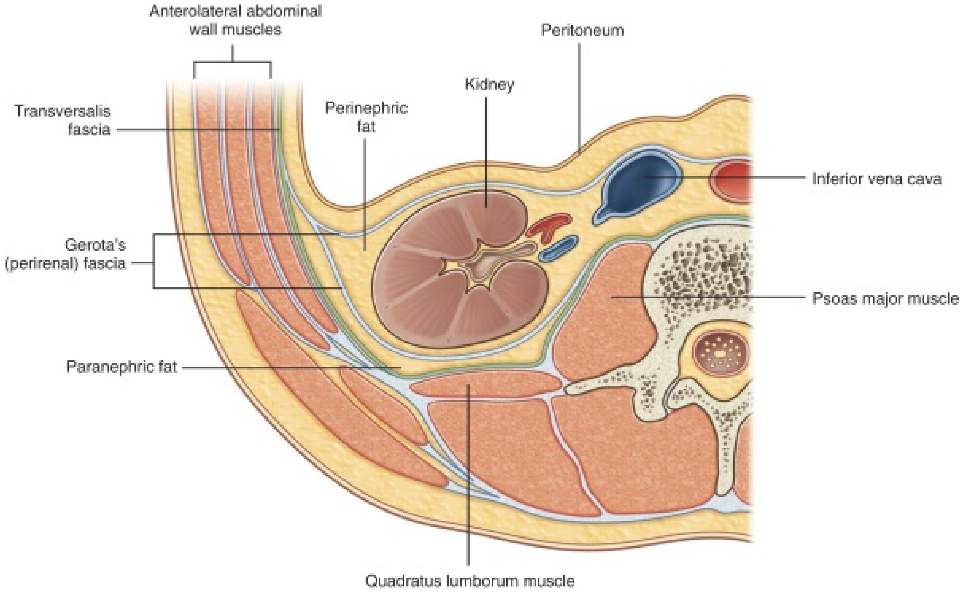

Fig. (5): Perirenal Coverings ***(Elspeth et al., 2002).***

The anterior and posterior layers of the Gerota's fascia subdivide the retoperitoneal space into three potential compartments:

P = **Posterior pararenal space** which contains only fat.

I = **Intermediate Perirenal space** which contains the suprarenal glands, kidneys and proximal ureters, together with Perirenal fat.

A = Anterior pararenal space which unlike the posterior and intermediate spaces, extends across the midline from one side of the abdomen to the other and contains the ascending and descending colons, the duodenal loop and the pancreas ***(fig.6)***.

(Elspeth et al., 2002)

In children, the perirenal fat is less than in adults and so, the child kidney is hypermobile.

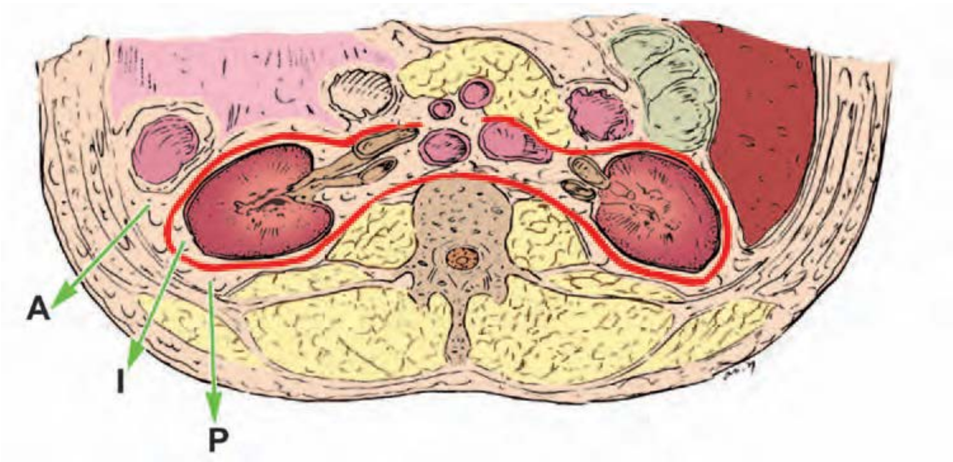

Fig. (6): Superior view of a transverse section of the kidneys ***(Smith, 2012).***

This arrangement of the renal fascia potentially separates the right and left perirenal spaces so, complications of the endourologic procedures e.g. (haematoma, urinoma, perirenal abscess) rarely involve the contralateral perirenal space ***(Elspeth et al., 2002).***

Kidney relationships with the diaphragm, ribs, and pleura with applied anatomy:

The posterior surface of the right kidney is usually crossed by the 12th rib and the posterior surface of the left kidney crossed by the 11th and 12th ribs. In this way, the posterior leaves of the diaphragm arches as a dome above the superior pole of the kidneys on each side. Therefore, when performing an intrarenal access, the endourologist may consider that the pleura and diaphragm are traversed by all intercostal punctures and by some punctures below the 12th rib ***(fig. 7)***, ***(Eichel and Clayman, 2007).*** So, lung and pleura are at risk of injury with intercostal punctures.

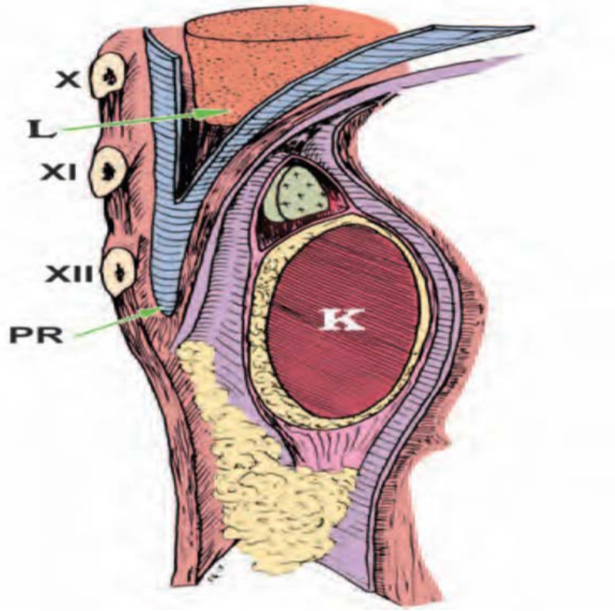

Fig. (7): Lateral view of the kidney and its relationships with the diaphragm, ribs, pleura and lung. **PR**= posterior reflection of the pleura, **L**= lower edge of the lung, **K**= kidney, **X**= 10th rib, **XI**= 11th rib, **XII**= 12th rib ***(Smith, 2012).***

Kidney relations with the abdominal viscera with applied anatomy:

The lateral, anterior, and medial renal relationships are varied **(Fig.8)**. **On the right side**, the liver is anterior to the upper pole of the kidney and can extend in some individuals to cover the entire anterior surface.

On the left side, the spleen covers less of the kidney anteriorly. Both the liver and the spleen can extend laterally to the kidney and so they are at risk of injury with a lateral puncture.

The ascending and descending colon can be lateral or even posterior to right and left kidneys, respectively ***(Drake et al., 2010).***

The apposition of the colon to the kidney varies with location; it is more on the left side and at the lower pole. In one study of computed tomograms the left colon was posterior in 16.1% of cases, and the right colon was posterior in 9% of cases at the level of the lower pole.

At the mid-aspect of the kidney the colon was posterior in 5.2% and 2.8%, respectively, and at the upper pole 1.1% and 0.4%, respectively ***(Boon et al., 2001).***

Colonic injury should be taken into consideration during PCNL interventions of the lower pole of the kidney (especially on the left side) due to the location of retrorenal colon.

Additional visceral relations to the kidney include the adrenal glands (medial to the upper pole of each kidney), the duodenum and gallbladder (anterior and medial to the right kidney), and the tail of the pancreas (anterior and medial to the left kidney). These structures can be injured with a misdirected or excessively deep puncture ***(Drake et al., 2010).***

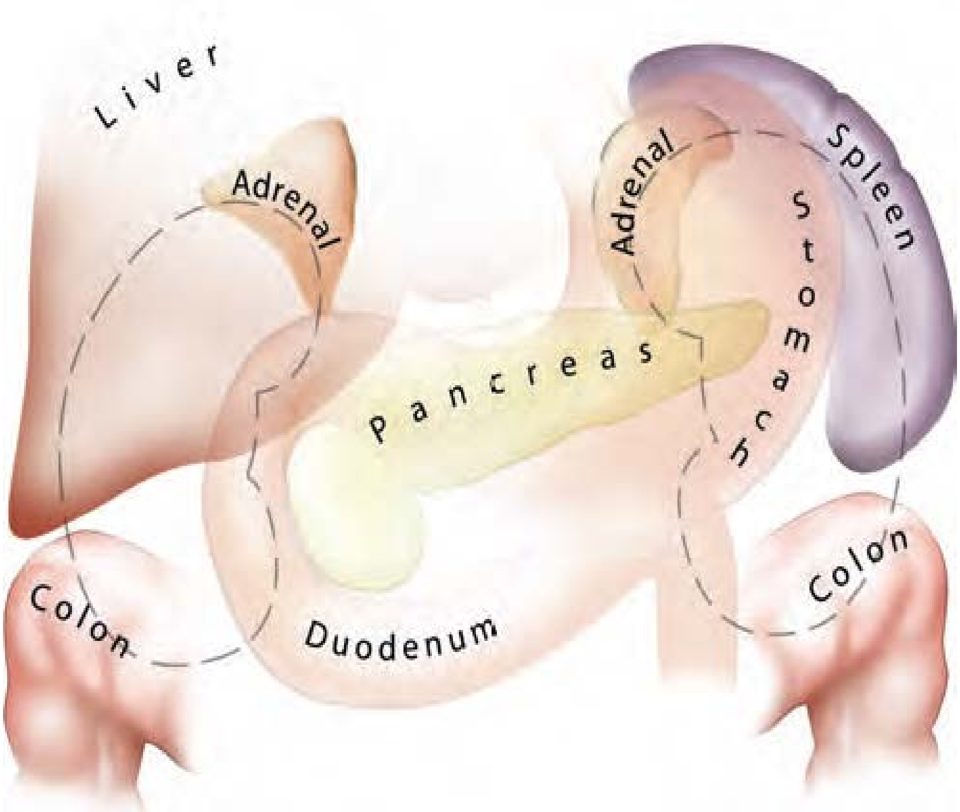

Fig. (8): Viscera; lateral, anterior and medial to the kidneys ***(Percutanous Approaches to the upper urinary tract collecting system. Campbell-walsh urology 11th edd. 2016 p.154)***

Internal structure of the kidney:

The renal parenchyma is composed of outer cortex and inner medulla. The renal cortex contains glomeruli, proximal and distal convoluted tubules while medulla contains the renal pyramids which are inverted cones that comprise the loops of Henle and the collecting ducts, which coalesce at the apex of the pyramid into papillary ducts that open on the surface of the renal papillae. There are approximately 20 papillary ducts draining into each papilla. The columns of Bertin are invaginations of cortical tissue that surround the renal pyramids except at their apices ***(Mader, 2004)***.

The renal papillae drain into the minor calyces. If only one papilla drains into a minor calyx, it is described as a simple calyx. When there are two or more papillae entering the calyx, it is termed a compound calyx. The outermost wall of the calyx, into which the papilla is set, is the calyceal fornix. There are 5 to 14 minor calyces in each kidney. There are three drainage zones: the upper pole, the mid zone, and the lower pole. Compound calyces are the rule in the upper pole and they are common in the lower pole, and rare among the mid zone. The minor calyces, either directly or after coalescing into major calyces, drain by infundibula into the renal pelvis The compound calyces of the poles of the kidney are oriented facing their respective poles, the simple calyces usually come in pairs, one facing anteriorly and the other facing posteriorly (Fig. 9) ***(Anderson et al., 2012).***

The upper pole always contains at least one compound calyx. Drainage of the upper pole into the renal pelvis is by a midline infundibulum in 98.6% of kidneys. The lower pole often contains a compound calyx as well. The lower pole is usually drained via a single infundibulum in about half of kidneys and through a series of paired anterior and posterior calyces in approximately half of kidneys. The mid zone calyces are typically arranged in a series of paired anterior and posterior rows in 95.7% of kidneys *(*Fig.*9)* ***(Anderson et al., 2012).***

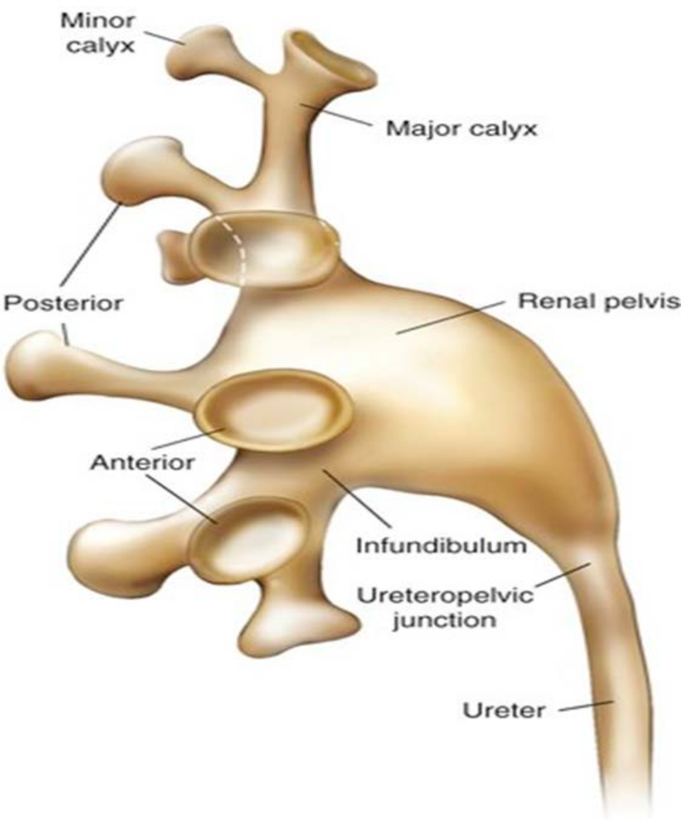

Fig. (9): Upper urinary tract collecting system ***(Percutanous Approaches to the upper urinary tract collecting system. Campbell-walsh urology 11th edd. 2016 p.155).***