1

Anatomy of the Human Ureter

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The ureter is a muscular tube, which connects the renal pelvis to the urinary bladder. Approximately 25 to 30 cm long, it has a diameter of about 3 mm. It has three natural constrictions. The first at the pelvi-ureteric junction, the second at the pelvic brim where it crosses the iliac vessels, and finally at the uretero-vesical junction (Figure 1.1). The narrowest part of the ureter is the intra-mural segment at the uretero-vesical junction [1].

The ureter traverses the retro-peritoneal space in a relatively straight line from the pelvi-ureteric junction to the urinary bladder. Lying in front of the psoas major muscle, its course can be traced along the tips of the transverse processes of the lumbar vertebrae [2].

Its posterior relations in the abdomen are the psoas major muscle and the genito-femoral nerve. The right ureter is covered anteriorly by the second part of the duodenum, right colic vessel, the terminal part of the ileum, and small bowel mesentery. The anterior relations of the left ureter are the left colic vessels, the sigmoid colon, and its mesentery. The gonadal vessels cross both the ureters anteriorly (Figure 1.2) in an oblique manner [3–6].

The ureter enters the pelvis at the bifurcation of the common iliac artery. The segment of the ureter below the pelvic brim is approximately of the same length as the abdominal part. It traverses postero-laterally, in front of the sciatic foramen and then turns antero-medially. In its initial course, it lies in front of the internal iliac artery, especially its anterior division and the internal iliac vein – an important relationship for the pelvic surgeon [6, 7]. It crosses in front of the obliterated umbilical artery, obturator nerve and finally the inferior vesical artery (Figure 1.2).

The relations with the adjacent organs from this part vary in both the sexes and are of clinical significance.

In the male, it is crossed by the vas deferens from the lateral to the medial side. The ureter then turns infero-medially into the bladder base just above the seminal vesicles.

In a female, the ureter passes behind the ovary and its plexus of veins – an important relation that makes it vulnerable to trauma during the ligation of these veins (Figure 1.2). It lies in the areolar tissue beneath the broad ligament. It is then crossed by the uterine artery, which lies above and in front of the ureter and yet again renders the ureter to injury. The subsequent part of the ureter bears a close relationship to the cervix and the vaginal fornix. It lies between 1 and 4 cm from the cervix. The course in front of the

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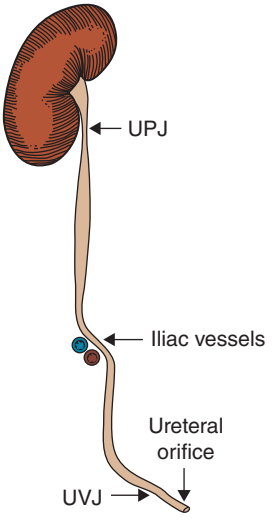

Figure 1.1 Anatomy of the ureter.

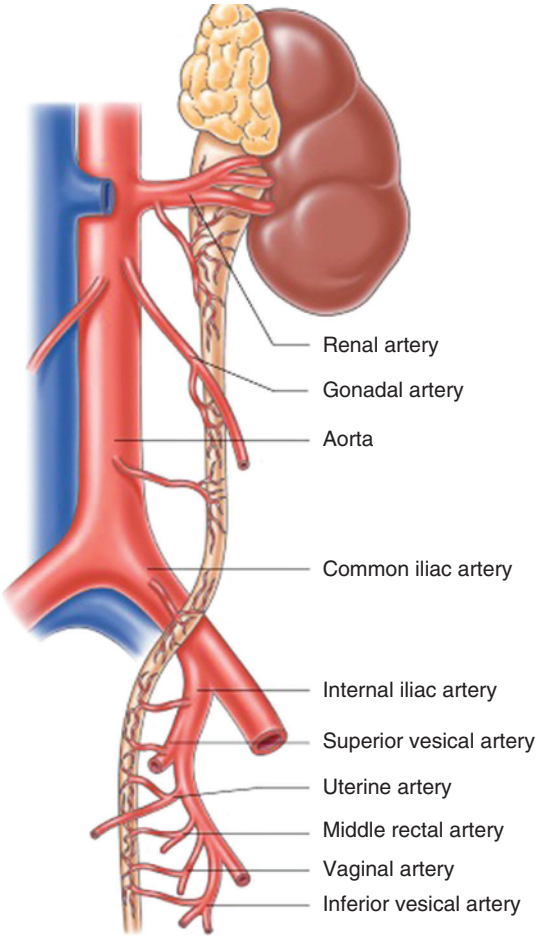

Figure 1.2 Blood supply of the ureter.

lateral vaginal fornix can be variable. The ureter may cross the midline and therefore, a variable part may lie in front of the vagina [8–10].

The intra-mural part of the ureter is oblique and is surrounded by the detrusor muscle fibres. Both these features result in the closure of the lumen and are responsible for prevention of reflux of urine during voiding. The two ureteric orifices are approximately 5 cm apart when the bladder is full. This distance is reduced when the bladder is empty.

1.1 Structure

The ureter does not have a serosal lining. It has three layers: the outermost, fibrous and areolar tissue, the middle, muscular, and innermost, the urothelial. The fibrous coat is thin and indistinct (Figure 1.3).

The smooth muscle fibers that provide the peristaltic activity are divided in circular and longitudinal segments. The inner, circular bundles are mainly responsible for the forward propulsion of urine. The longitudinal coat is less distinct in its proximal part. Additional longitudinal fibers are seen in the distal part of the ureter. The muscle coat of the ureter is rarely arranged in two specific layers.

The inner, urothelial lining is of transitional epithelium. It is four to five cell layers thick in the main part of the ureter but is much thinner in its proximal part where it is two to three cell layers (Figure 1.3). It has very little sub-mucosa. Mostly folded longitudinally, it merges with the urothelium of the bladder at the distal end.

1.2 Blood Supply

The ureter draws its blood supply in a segmental fashion (Figure 1.2). There is a good anastomosis between the arterial branches arising from renal artery, abdominal aorta, gonadal vessels, common iliac, internal iliac, superior and inferior vesical arteries. Ureter also has branches arising from the uterine artery in females. Despite the extensive

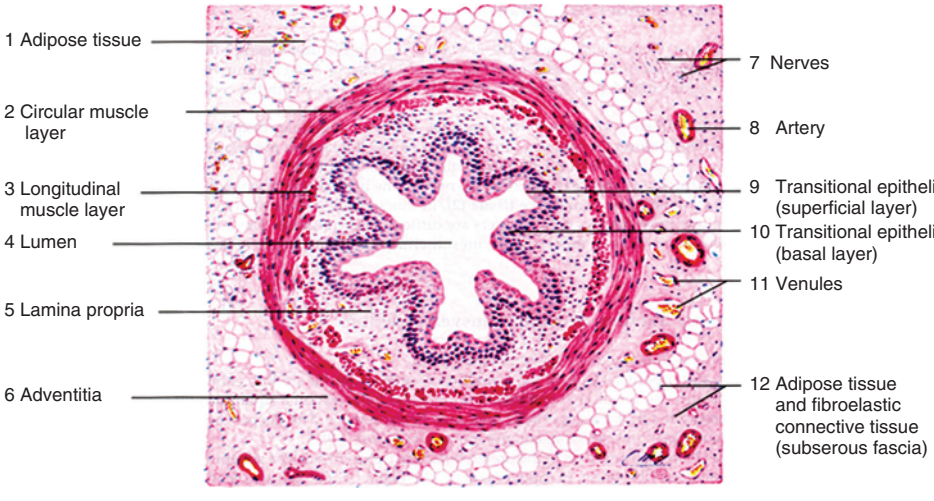

Figure 1.3 Histology of the ureter.

internal anastomoses, the blood supply of the distal 2–3 cm of the ureter is unpredictable [9]. This makes this segment vulnerable to ischemia if dissected excessively.

The venous drainage of the ureter follows the arteries and ultimately leads into the inferior vena cava.

Lymphatic drainage of the ureter is also segmental. The internal, communicating plexus of lymphatics within the walls of the ureter drain into the regional lymph nodes. The lymphatics from the proximal part of the ureter drain into the para-aortic lymph nodes near the origin of the renal artery. The distal abdominal segment drains in the para-aortic as well as common iliac lymph nodes. The lymphatics from the pelvic segment of the ureter drain into the internal and subsequently into the common iliac lymph nodes [10–12].

1.3 Nerves

The autonomic nerve supply of the ureter arises from the lumbar and sacral plexuses. The proximal part of the ureter derives the nerve supply from the lower thoracic and the lumbar plexus whereas the distal and pelvic part from the sacral. Pain fibers to the ureter predominantly arise from L1 and L2 segments, which explain the referred pain to the relevant dermatome. The nerve fibers are sparse in the proximal part but plentiful in the distal segment. Ureteric peristalsis is largely independent of its innervation. A downward wave, initiated in the collecting system, much like the sino-atrial node in the heart, is believed to be responsible for the forward propulsion of urine towards the bladder. A paralysis of this intrinsic neuro-muscular activity can occur due to an obstructive or inflammatory process.

1.4 Embryology

Ureteric buds develop and grow in a cephalad fashion from the embryonic bladder. The superior ends of these buds are capped with the meta-nephros, which develops in to the adult kidney (Figures 1.4 and 1.5). The proximal extension of the ureteric bud develops into the renal pelvis, calyces and the collecting tubules. Meta-nephros, which develops from the mesoderm, forms up to 1000,000 nephrons, which join the collecting tubules to form the final functional units of the adult kidney. Once the meta-nephros and the developing collecting system have reached its lumbar destination, it gains attachment to the adrenals. Medial rotation of the embryonic kidney results in alteration of relationship of both kidneys to the neighbouring organs.

The separation and proximal growth of the ureteric buds has an important bearing on the ureteric and renal anomalies. The lack of separation of the meta-nephros will lead to the development of a horseshoe kidney (Figure 1.6). Similarly, any deviation in the normal development of the bud will lead to duplex or fused ectopia.

1.5 Congenital Variations

1.5.1 Reto-caval ureter

The right ureter may cross behind the inferior vena cava (retro-caval ureter). The incidence is reported to be 1 in 1500 patients. More common in males than in

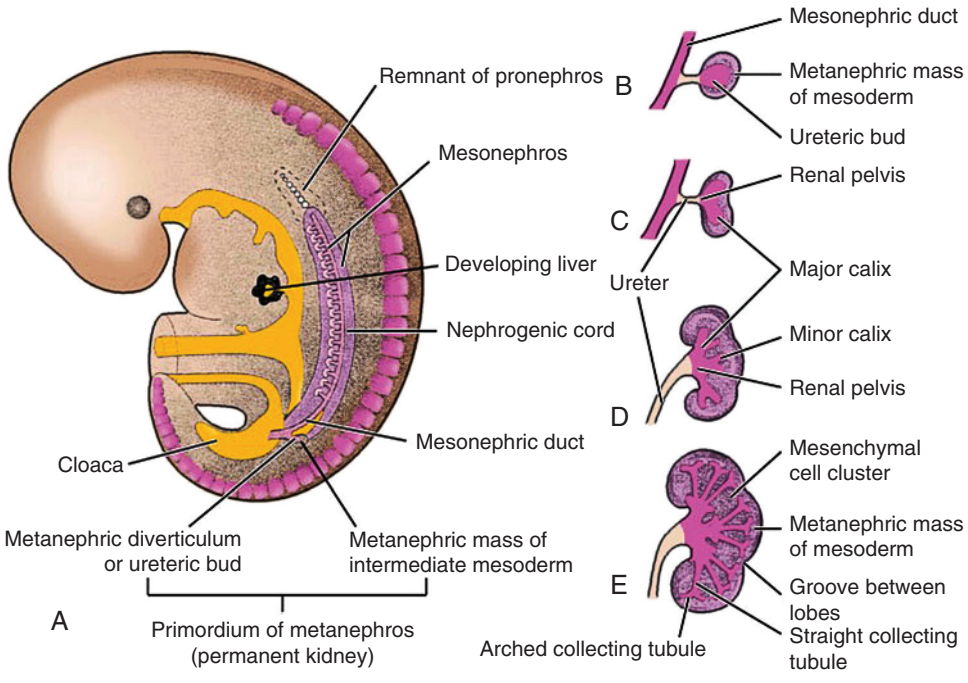

Figure 1.4 Ureter embryology, part one.

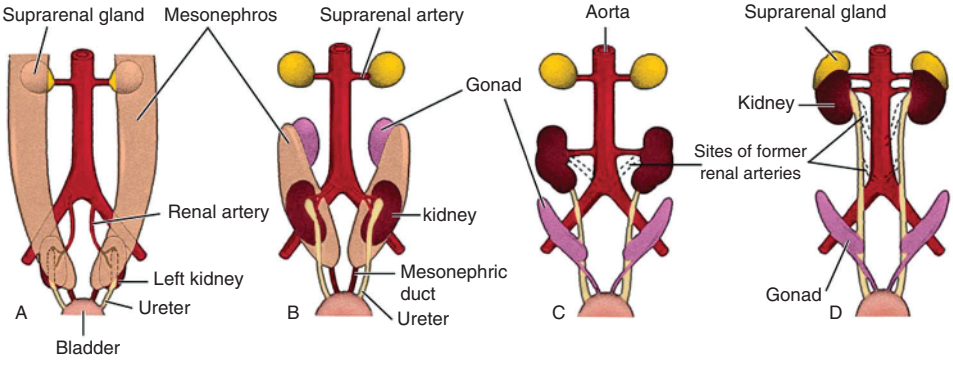

Figure 1.5 Ureter embryology, part two.

females, this congenital variation is considered an anomaly of the development of the vena cava rather than the ureter. So, the term pre-ureteral cava is more appropriate (Figure 1.7).

1.5.2 Duplex

Duplication of the ureteric bud may result in a variety of anomalies. This may be in the form of two separate systems on both sides or a duplex ureter at variable levels which get fused anywhere from the PUJ to the ureteric orifice. The location of the ureteric

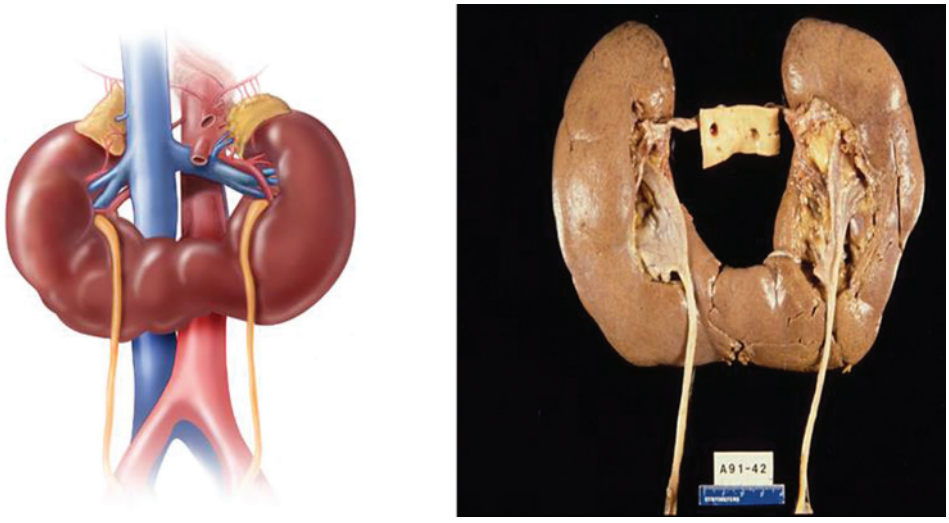

Figure 1.6 Horse-shoe kidney.

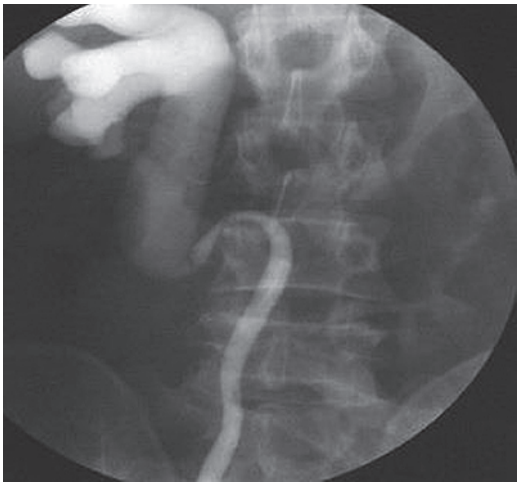

Figure 1.7 Retro-caval ureter.

orifices of a duplex system is governed by what is known as the Weigert-Meyer law, which states that the ureteric orifice of the upper moiety is more medial and caudal where as that of the lower segment is more cranial and lateral (Figure 1.8). The upper moiety is usually small and its ureter is more likely to suffer with obstruction or an ureterocoele. The lower moiety is more prone to reflux.

1.5.3 PUJ Obstruction

A functional narrowing of the uretero-pelvic junction results from muscular hypoplasia or a neuro-muscular abnormality. A lack of the progression of the peristaltic wave at this location results in functional obstruction. Progressive dilatation of the renal pelvis

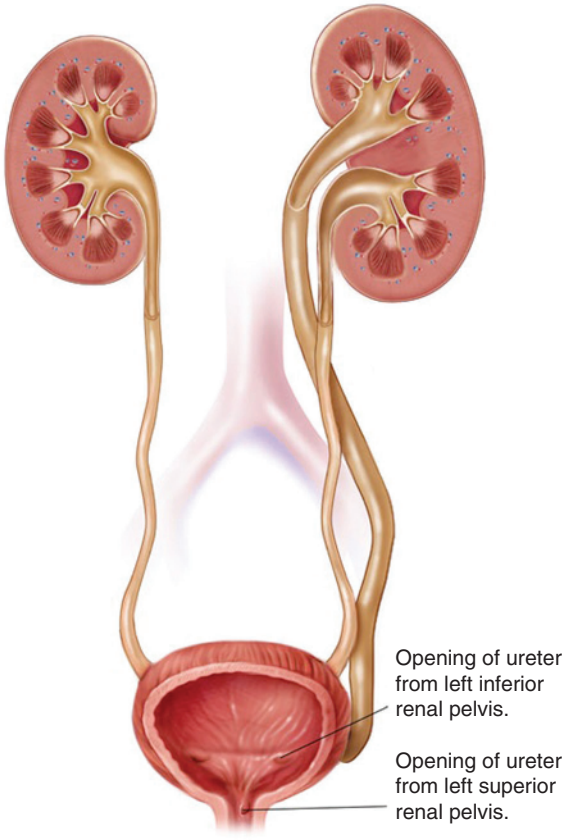

Figure 1.8 Duplex ureter.

follows and causes stasis. These two features lead to complications such a formation of calculi, infection, pain, and a progressive loss of renal parenchyma if corrective surgery is delayed.

Other variations include a high attachment of the ureter to the pelvis, a long segment of atresia and segmentation of the renal pelvis. Associated with a PUJ obstruction, the renal artery or its branches may cross the ureter, potentially leading to obstruction. The role of crossing vessels near the pelvic-ureteric junction and their influence on obstruction to the upper tract is often difficult to assess. Whether they lead to the dilatation of the renal pelvis or the latter appears obstructed due to the over-hang is often debatable.

1.5.4 Ectopic Ureteric Orifice

This rare form of anomaly is often seen with the upper moiety of a duplex system. In a fully developed single renal unit, the ureter may drain in the posterior urethra, seminal vesicle, or the vas deferens. In a female, the orifice may be in the urethra, vagina, or the perineum, and presents with incontinence.

1.5.5 Ureterocoeles

Usually seen in the upper moiety of a duplex system or an ectopic ureter, these are due to the failure of canalization of the ureteric bud.

1.5.6 Mega-Ureter

A grossly dilated ureter with a narrow uretero-vesical junction is the typical appearance of this condition. An a-peristaltic segment of the distal segment is the possible cause. There may be an associated reflux. This anomaly may be seen with other abnormalities such as prune belly and other syndromes.

1.5.7 Ureteric Diverticulae

This rare anomaly is due to the variation in the development of the ureteric bud.

1.6 Clinical Significance

The importance of anatomy of any organ cannot be over-emphasised to a surgeon.

Awareness of the normal anatomy and its variations can help the surgeon to avoid trauma during procedures that involve dissection of the ureter. Accidental tears, trans-section, ligation, heat damage caused by diathermy, ligasure, harmonic scalpel, or laser energy can be reduced by careful separation of the ureter. Such heat damage can be subtle and manifest much later when tissue necrosis develops following ischemia. The knowledge of the blood supply is important. Avoiding excessive mobilization can prevent the development of ischemic strictures following ureteric surgery. Although distensible, the diameter of the ureter should be respected. Insertion of wide-bore instruments invariably leads to tears and subsequent scarring. Increasing use of ureteroscopy and the use of devices such as lasers has led to a rise of iatrogenic ureteric trauma.

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