Ureteric Stenting
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Ashford and St Peter’s Hospitals NHS Foundation Trust, UK
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Foreword

The Urology World has long awaited a book entirely devoted to ureteral stents.

Dr. Kulkarni has assembled an impressive selection of contributors to this book all of whom are experts in the field. Various types of stents are described and all aspects of stenting, including techniques of insertion and the complications that may ensue, are discussed.

It is now a relatively simple matter to insert a ureteral stent either to overcome an obstruction or to prevent it. Indeed, too frequently, ureteral stents are inserted with no thought given to the problems that may arise when they are subsequently removed (see chapter 20).

For example, patients with bilateral ureteral obstruction caused by a malignancy are invariably stented without discussing with the patient and/or family the alternative of non-intervention. In many instances, a fairly rapid demise from uraemia may in fact be preferable to stenting a patient and extending a life of poor quality and severe pain.

My single message to the readers of this book is that the possible consequences of stenting should always be considered before embarking on this form of therapy.

I congratulate Dr. Kulkarni for this major contribution to the urologic literature. This book will certainly be appreciated by its readers and will be invaluable in the treatment of their patients.

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Preface

Ureteric stenting is one of the most common urological procedures. The idea of writing a book on the subject seemed like stating the obvious. But when I thought about the subject, it lent itself as a little challenge. The changes in designs, materials and the evolution of technical alternatives over the past decades alone have been so extensive that a compilation felt worthwhile.

Many enthusiasts have done sterling work on different aspects of stents. These contributions have been published and are well recognised. However, not many have reached the operating theatres of the practicing urologist nor have these advances passed on to the patients who would benefit from these modifications. Making the urological community aware of these seemed like a good idea.

Original research on the physiology of the ureter to the new biodegradable materials has enriched our knowledge and has provided a platform to consider alternatives. The quantification of stent related morbidity and the cost benefits have also been brought to our attention in the new cost-conscious world in which clinical practice is critically evaluated.

This treatise of a wide spectrum of chapters written by some of the well-recognised authorities in the world will provide a valuable source of scientific and practical information to all those involved in managing ureteric obstruction. Aimed at all levels of urologists and radiologists, this book will hopefully offer some technical as well as conceptual hints. I anticipate, it will also generate enthusiasm so necessary to keep innovation at the forefront of this field.

I am most grateful to all the authors for their efforts and the time. Special thanks to Prof Arthur Smith, whose advice from the very concept to the selection of topics has been of enormous value.

I would like to thank my wife Meena for putting up with me during this work!

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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 genitofemoral 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···
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.](image-url)
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
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
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 whereas 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 ureterocele. 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
follows and causes stasis. These two features lead to complications such as 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 Ureteroceles

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.

References


A normal ureter is a narrow, tubular structure that carries urine between the renal pelvis and the bladder. Far from a passive tube, the ureter has three distinct muscular layers surrounding a specialized urothelium, which actively propels urine to the bladder. The ureter narrows at distinct points along its course including the ureteropelvic junction (UPJ), the ureteral segment over the iliac vessels/pelvic brim, and the ureterovesical junction (UVJ). These act as common points of obstruction for a passing stone. However, variations in normal anatomy result in a higher likelihood or even increased degree of obstruction, and present several challenges to stent placement.

### 2.1 Horseshoe Kidney

Horseshoe kidney (HSK) is the fusion of the right and left kidneys at their lower pole across the midline. The point of fusion is referred to as the isthmus and varies in quality from a thin, fibrous band to thicker, functional renal parenchyma. HSK occurs in about 1 in 400 to 666 individuals and is twice as common in men [1, 2]. The higher incidence of HSK seen in children can be explained by the co-occurring non-urologic comorbidities limiting their overall survival. Associated urologic abnormalities include UPJ obstruction (17%), vesicoureteral reflux (20–50%), and ureteral duplication (10%).

Normally, kidneys ascend to the upper retroperitoneum, just below the liver or spleen. They rest on the psoas muscles resulting in a line with the upper pole slightly more medial to the lower pole. With HSK, the isthmus is tethered by the inferior mesenteric artery limiting kidney ascent resulting in the lateral rotation of the upper poles with an anterior displacement of the renal pelvises [3].

The ureter has a high insertion into the renal pelvis in HSK with an increased incidence of ureteropelvic junction (UPJ) obstruction of about 13–35% [2]. Moreover, the ureter courses over the isthmus creating another point of obstruction and urinary stasis, raising the risk of nephrolithiasis and urinary tract infection (UTI) [4–6].

Management of stones offers several challenges in patients with HSK given their abnormal renal and ureteral anatomy. Shock wave lithotripsy (SWL) is an option;
however, the reliance on passive clearance results in poor stone free rates (31–70%) [7, 8]. Ureteroscopy is plausible and one series was able to demonstrate excellent stone-free rates in patients with stones ≤10 mm [9]. Larger stones up to 16 mm were more likely to have residual fragments or require multiple procedures.

PCNL offers the best outcomes regarding stone-free rates (75–100%) [7, 8, 10]; however, major complications including bleeding, sepsis and bowel injury are more common, albeit still rare. Given the lower position and abnormal rotation of HSK pre-operative cross-sectional imaging is paramount to accurately assess stone burden and also proximity of major blood vessels and organs including bowel and pleura. The antero-medial rotation of the lower pole results in the upper poles being the most posterior region of the HSK and so the preferred point of access. Patients with HSK have a higher incidence of retrorenal colon (3–19%) and as such are at an increased risk of bowel perforation during percutaneous access [11, 12].

In other cases of renal ectopia with or without fusion are far less common than HSK [13]. Ureteral anomalies similar to HSK continue to occur and their course is dependent on the kidneys final position relative to the intended ipsilateral trigone.

2.2 Duplex Ureter

The incidence of upper tract duplication is 0.5 to 0.7% of the asymptomatic population and 1% to 10% of children with UTIs [14]. The most common variation is a partial duplication (70%) with a common ureter entering the bladder [15]. Complete duplications are more likely to have additional comorbidities including reflux, ureteral obstruction, or ureterocele. Ureteral duplication is difficult to appreciate on a non-contrast CT scan and contrast enhancement is suggested when suspicion is high [16]. The Weigert-Meyer rule dictates that in a completely duplicated system, the lower-pole moiety implants more laterally in the bladder with a shorter intramural segment more prone to reflux [17]. Conversely, the upper-pole moiety implants caudally and is more likely to be ectopic and obstructed.

Stent placement in a partially duplicated ureter can be challenging. If electing to only stent a single system, the surgeon should chose a stent with side holes throughout its entire length. If retrograde wire placement does not preferentially cannulate the desired moiety, an angled-tip catheter can direct a glidewire at the point of bifurcation. Alternatively, ureteroscopy with direct visualization of the desired ureter at its bifurcation may be required. If a retrograde approach is unsuccessful, percutaneous antegrade ureteral stent is preferred. Surgeons should consider stenting both moieties to prevent de novo compression and obstruction of the unstented moiety.

2.3 Megaureter

A normal ureteral diameter is between 3–5 mm. Dilation greater than 7 mm may be considered a megaureter [18]. Etiologies include primary or secondary (due to bladder outlet obstruction) reflux, or ureteral obstruction attributable to segmental narrowing or aperistalsis. Megaureters have been described as obstructing and refluxing; however, this combination is less common [19]. Aperistaltic dilation without obstruction is thought to be secondary to abnormal muscle fibers or collagen deposition [20].
Congenital megaureter is primarily a pediatric diagnosis, often diagnosed in utero given the near ubiquitous use of neonatal sonographic screening. For children who escape discovery or remain asymptomatic, about half spontaneously resolve without the need for intervention [21, 22]. Congenital megaureter diagnosis in adults is rare and proceeded by symptoms secondary to obstruction or infection. Ureteral stones, which developed due to urine stagnation in the dilated segment have been described in 36% of patients with symptomatic megaureter [23].

Megaureter management derived from the pediatric literature states a primary goal of renal preservation [19]. Surgical management includes excision of the obstructing segment, tapering to allow for a normal length to diameter ratio, and re-implantation. In adults with obstructed megaureter, treatment may be indicated in the setting of recurrent urinary infections, ureterolithiasis, pain, or renal deterioration. Near complete loss of renal function secondary to longstanding obstruction may warrant simple nephrectomy rather than a salvage procedure. Percutaneous decompression with interval functional assessment would help guide surgical planning in this regard. Surgical tapering and reimplantation have been described in adults with good success. A less invasive approach with ureteral meatotomy and stenting has also been described and useful for patients with ureteral calculi [23].

Non-orthotopic ureteral reimplantation and irregularities in the inner lumen following megaureter repair may make subsequent ureteral stenting and instrumentation difficult. Antegrade percutaneous intervention or stent placement should be considered in these cases.

### 2.4 Ectopic Ureter

An ectopic ureter is a ureter that does not implant in the trigone of the bladder [24]. Similar to ureteroceles, the exact mechanism that results in ureteral ectopia is unknown; however, it is thought to be related to abnormal ureterotrigonal development [25, 26]. As stated earlier, following the Weigert-Meyer rule, ectopic ureters in a duplex system are commonly associated with the upper pole moiety and likely to be obstructed especially when implanted proximal to the external sphincter above the pelvic floor [17].

Ectopic ureters usually implant in a Wolffian structure, which in males include the vas, seminal vesicles, or ejaculatory ducts [26]. In women, an ectopic ureter may have a wider range of implantation from the bladder neck to the vagina, rectum, and perineum [27]. A young girl presenting with signs of continuous incontinence or dribbling while still voiding spontaneously should raise suspicions of an ectopic ureter distal to the bladder neck and should be investigated accordingly.

### 2.5 Ureterocele

A ureterocele is defined as a cystic dilation of the terminal portion of the ureter. The exact embryologic mechanism by which ureteroceles form is unknown; however, abnormal ureterotrigonal development, a defect in common nephric duct apoptosis, and failure in rupture of the distal membrane at the ureteral orifice are likely contributing events [25, 26]. Not all ureteroceles are obstructive and the cystic appearance of the
non-obstructive variety is likely a result of poor muscularization and ballooning of the distal ureter.

Ureteroceles may be classified into two subtypes: intravesical ureterocele inserts into the bladder and is confined within its lumen; extravesical ureterocele results from an ectopic insertion of the ureter, commonly into the bladder neck or urethra. A cecouretterocele combines an ectopic with an intraluminal orifice. The result is a prolapsing ureterocele that obstructs the bladder outlet. Ureterocele incidence ranges from 1 in 500 to 1 in 1200 individuals and is 6 times more likely to affect women [26, 28]. Approximately 80% are associated with a duplicated system and affect the upper pole moiety, and 10% are bilateral [26].

Antenatal sonography has rendered ureteroceles primarily a pediatric diagnosis. Children often have concomitant hydronephrosis or UTIs, and treatment aims to prevent infection, maximize renal function, and preserve continence. In symptomatic patients or in the setting of hydronephrosis, endoscopic puncture using a Bugbee electrode, or more recently, a laser is regarded as the treatment method of choice [29].

Adult ureteroceles are less commonly encountered and are likely to be intravesical and orthotopic [26]. Ureteral atony with stasis increases the risk of ureteral stone formation to 4–39% of patients [30]. With the increase risk of ureteral stones, holmium laser unroofing with ureteroscopy and laser lithotripsy has been described [31]. In our own experience, adult ureteroceles tend to be thick-walled and a simple puncture is inadequate. Rather, a longitudinal incision or complete resection especially in the setting of prolapsed and bladder neck obstruction is necessary.

Anatomic variations can result from abnormal kidney development and localization, or are dependent on the embryologic development of the ureter relative to the bladder. Deviations from the normal anatomic course of the ureter increase the risk of ureteral obstruction and dilation resulting in a higher incidence of urinary stasis, urolithiasis, and infection. Surgical intervention should be reserved for symptomatic individuals or for cases that will preserve renal function.

Prior to operating on a patient, cross-sectional imaging with contrast and delayed-phase urogram will help delineate variant vasculature, the ureteral course, and the relative location of adjacent organs that may be different from those with normal anatomy.

References

Ureteric Stenting


3

The Pathophysiology of Upper Tract Obstruction

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3.1 Introduction

Obstruction of the upper urinary tract is a common clinical problem in urological practice. Obstruction to drainage of urine at any point along the urinary tract is termed an obstructive uropathy. This can lead to irreversible damage to the renal parenchyma with functional impairment described as obstructive nephropathy. Several factors determine how an obstructive uropathy will affect a kidney as well as the likelihood of this developing. These factors include characteristics of the obstruction – unilateral or bilateral, partial or complete, as well as the duration of obstruction together with underlying characteristics of the kidney (pre-morbid function and renal anatomy).

3.2 Aetiology

Upper urinary tract obstruction may relate to pathology affecting either the ureters (supra-vesical) or lower urinary tract conditions that impair bladder emptying (vesical or infra-vesical). The causes of upper tract urinary obstruction are shown in Table 3.1. These can relate to intra-luminal or mural (either intra-mural or extra-mural) pathology. Intra-luminal causes are the most common and ureteric calculi comprise the majority of cases in clinical practice. Intra-mural causes relate to conditions of the ureteric wall resulting in stricture formation from ischemia or urothelial malignancy or functional obstruction due to impaired peristalsis exemplified by congenital uretero-pelvic junction obstruction. Extra-mural obstruction compromises the ureteric lumen and peristaltic activity by mechanical circumferential compression of the ureter.

Intra-luminal obstruction frequently results in acute obstruction, which may be high grade, although partial chronic obstruction may also arise or subsequently evolve.

In contrast, mural causes (both intra and extra-mural) tend to present more insidiously but can progress to complete or high-grade obstruction over time. Obstruction primarily related to conditions arising from or within the ureter tends to be unilateral.