60 Ureteric Stents: Their Use and Abuse

Stuart J. Graham and Simon Choong

Abstract

Ureteric stents are used to prevent or treat obstruction of the urine flow from the kidney or to allow appropriate healing after a procedure on the renal pelvis or ureter. Placement of stents is in most circumstances a simple procedure if care is taken to follow a few principles. They can be inserted retrogradely up the ureter or percutaneously down the ureter. Stents are made of soft, synthetic material with memory molecules that uncurl to facilitate insertion, but remain coiled in the human body after placement. Stents have a limited life when inserted into the human body. They are prone to encrustation and upward migration and can easily be forgotten unless there is a tracking system to record and remind patients of the due date of removal.

Keywords

Bladder • Biofilm • Catheter • Encrustation • Hydrophilic • Guidewire • Percutaneous • Ureteroscope • Ureteric stent • Urine • History

Introduction

A ureteric or ureteral stent is a thin prosthetic device, often tubular, inserted into the ureter to prevent or treat obstruction of the urine flow from the kidney or to allow appropriate healing after a procedure on the renal pelvis or ureter. Often considered a necessary evil, these very necessary devices can cause significant morbidity, which needs to be clearly understood when counseling a patient prior to their insertion.

The classic ureteric stent most commonly in use today is the "double pigtail" design that involves a long and narrow central portion, normally hollow to allow easy placement, with a complete curl at either end (Fig. 60.1). As the stent is made usually of a soft, plastic type biomaterial (Fig. 60.2), these end pieces completely uncurl to facilitate insertion, but remain coiled inside the human body after placement, to hold the stent in place. The lower curl stops upward migration into the kidney, making retrieval from the bladder easier, and the upper curl stops the stent from falling out.

Not all stents are such hollow tubes. Several companies make solid stents that may be placed in conditions that cause significant ureteric obstruction such as in compression due to intra-abdominal tumors (Fig. 60.3). The basis for their use is that they tend to be incompressible, and small grooves in the stent wall allow urine passage. They are technically more difficult to place, however.

Another type of device used in compressive ureteric disease is the Memokath® stent (Fig. 60.4a–c). This is a metal coil placed permanently within the ureter that holds the wall fully open. They may also be difficult to pass and require a section of normal ureter below the stent.

Much of the development of stents in recent years has focused on increasing the in vivo life of the device using novel biomaterials to resist encrustation and infection, and

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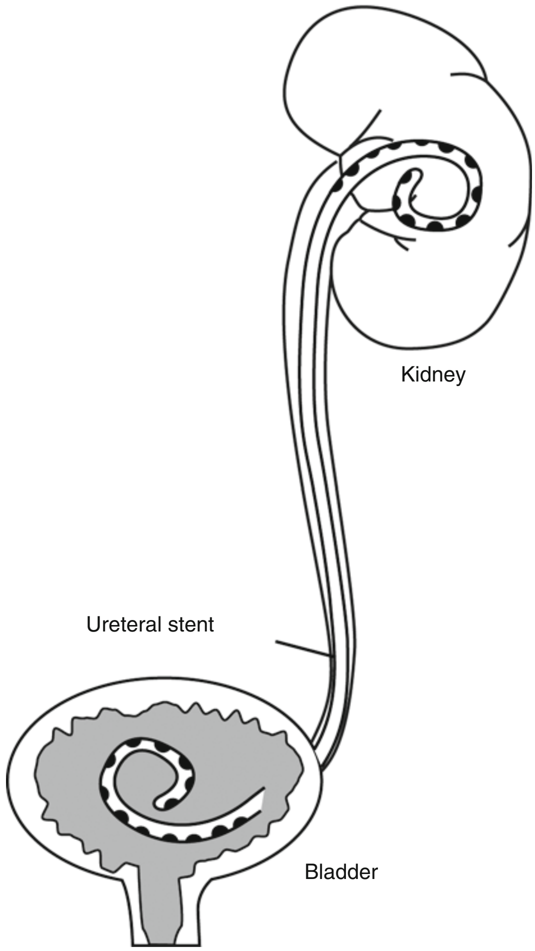

Fig. 60.1 Left side of the urinary tract containing a ureteric stent

Fig. 60.2 The upper curl of a typical JJ stent. Note the tapered end, the black mark that shows the start of the coiled portion and the multiple side holes

Fig. 60.3 A solid metal coil stent. Note the coiled groove running round the side of the stent (Permission for use granted by Cook Medical Incorporated, Bloomington, IA)

increasing the patient comfort, by altering the lower end and shaft of the stent and by softening at body temperature.

The History of the Ureteric Stent

The first ureteric stents were used to aid alignment of the cut ends in ureteric anastomotic surgery. The first described case is by Gustav Simon in the nineteenth century [1]. True endoscopic placement had to wait until the development of cystoscopy in 1876 by Nietze [2].

Initially, ureteric catheters were made from materials such as varnish-coated fabric (Fig. 60.5). Plastic replaced this, which was easier to place and more robust. The catheters would run through the bladder and out to an external drainage bag. However, the rate of infections and therefore encrustation and blocking was very high. In 1952, Tulloch [3] used polythene tubing to repair a ureter. In 1967, Zimskind et al. [4] described the use of a silicone device and introduced it cystoscopically.

These devices all had the problem that, being straight tubes, they migrated easily out of the ureter, into the bladder,

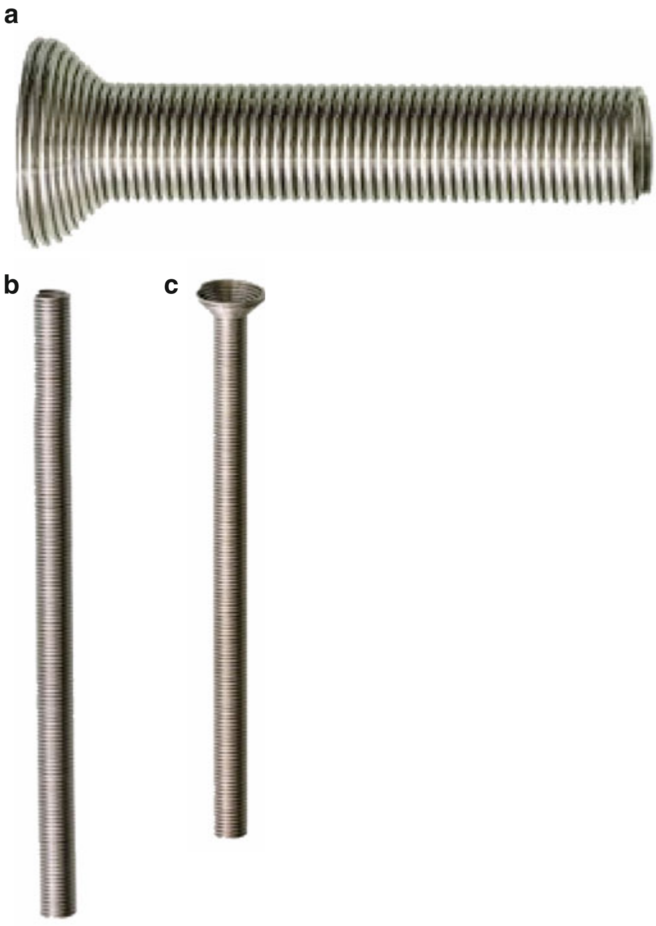

Fig. 60.4 (**a**) A Memokath stent, in the flange-ended configuration. A Memokath stent (**b**) before and (**c**) after thermal expansion

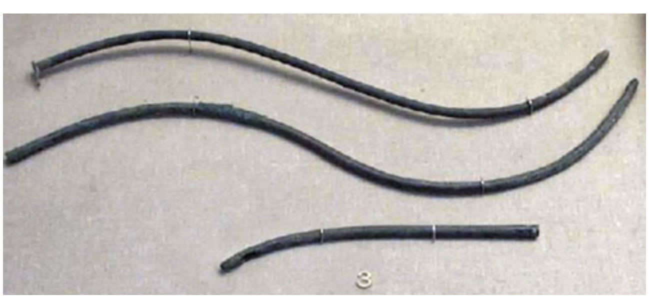

Fig. 60.5 Ancient lead catheters (Courtesy of British Museum)

thus losing their function. The modern stent derives its shape and characteristics from strategies developed to overcome movement. Gibbons et al. [5] devised a catheter with molded barbs, which reduced the rate of expulsion. The barbs increased the external diameter, making placement tricky, as did later attempts to address this problem, using a distal flange.

Hepperlen and Mardis [6] described the first design with a curled or "J" tip in 1978. This device had a curl at the top

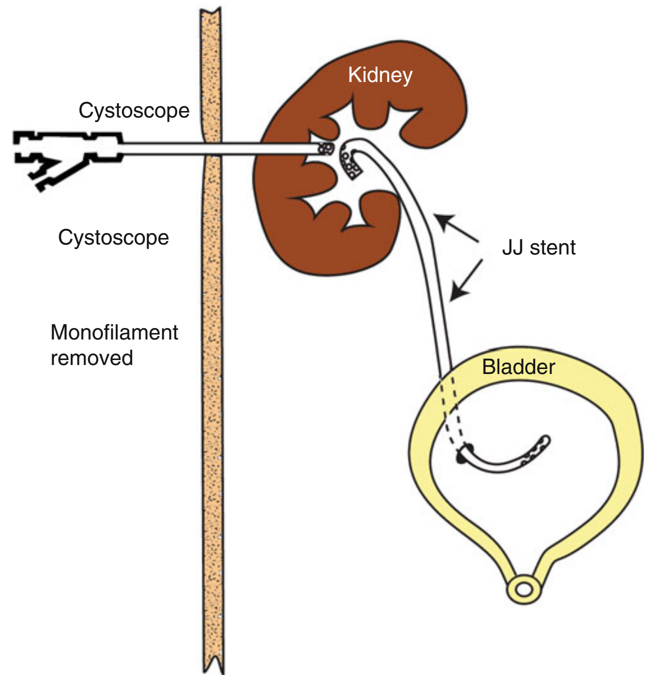

Fig. 60.6 Description of placing the Finney JJ stent (Adapted [7])

Fig. 60.7 Endopyelotomy stent. Note the change in diameter to allow a widened ureteric caliber during healing

end that was placed into the kidney, but no provision was made to prevent proximal movement of the device.

Finney [7] described the first "double-J" stent in 1978 (Fig. 60.6). It had a constant diameter and, being hollow, could be mounted on a wire, straightening the curl at the leading end to facilitate placement, and placed via a cystoscope. The stent thus created was used primarily to bypass

Fig. 60.8 Grooved tower stent

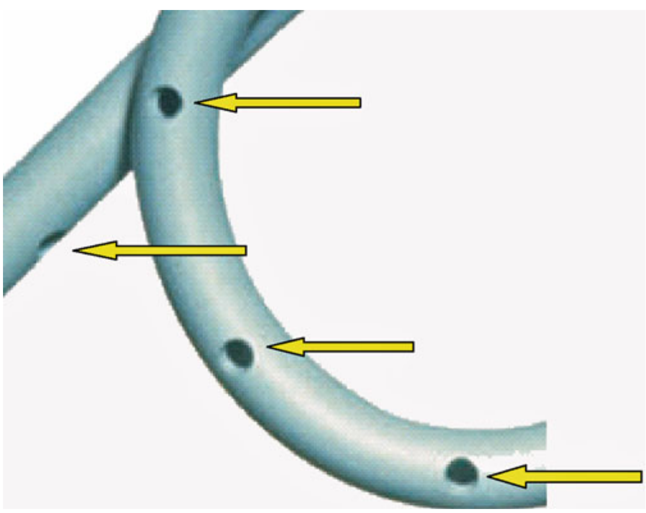

Fig. 60.9 Close up of stent showing side holes (*arrows*)

malignant obstruction, but over time, its use has expanded to protective and other treatment roles.

Each step in the design process has modified the stent to a more "ideal" state. The ideal appliance will give benefits both to the surgeon placing it and the patient, in whom it is being placed. For the surgeon, the stent needs to be easy to handle, easy to place, easy to remove, but not migratory while in place. From the patient's perspective, the stent must be comfortable, with as few side effects as possible. It needs ideally to be placed and removed or replaced with the minimum of time and effort.

To that end the modern double-J stent is hollow, usually of constant diameter (Fig. 60.7), made of a polymer, with or without a coating, and with or without holes along its length possibly to facilitate drainage. The stent is also radiopaque to facilitate its positioning by fluoroscopy.

Stent designers have tried other strategies for anchoring the device in place. Single and multicoil devices have been used. As one might expect, single coil stents tended to migrate more, and there are reports of multicoil stents knotting, requiring percutaneous removal. Stent variations abound, including the use of grooves (Fig. 60.8) and helical screws.

Side holes are a regular feature of stents (Fig. 60.9), although their original purpose is difficult to ascertain. Certainly some researchers feel that they have a detrimental effect on peristaltic function, and some do not use them in their design at all. This assertion has been questioned in animal studies that show the main determinant on reducing peristaltic function is stent diameter. There is, however, some evidence that the presence of side holes may be useful. In one study, a stent containing no holes, the Tower stent, was compared to other stents with side holes. The holeless stent performed badly with regard to drainage properties.

The usefulness of the stent as a hollow tube has been described previously. However, it does not necessarily mean it is the best shape from a consideration of fluid dynamics. Little work has been done on the flow dynamics of the ureter containing a solid stent. There are, however, some devices that used a solid portion of stent for part of their length. However, the inability to use a guidewire for its placement has meant that it has not found favor with most surgeons.

Materials Used in Ureteric Stents

The modern ureteric stent is usually made of a synthetic polymer called a biomaterial, which has several physicochemical properties that aid its placement and comfort while inside patients. These stents are smooth and have a surface to which other chemicals can be bonded, either to aid placement, such as hydrophilic coatings, or to make the stent smoother or have a lower surface energy to resist complications such as encrustation. The polymer is flexible and pliable such that it is easy to uncoil during placement, has memory so that it coils again after placement, and has a degree of elasticity so that it resists fracturing of continued patient movement and during removal.

However, polymers are not the only material used to make stents. The Memokath stent is a metallic coil made of a nickel titanium alloy (nitinol) and has a wide lumen that resists compression. It can be used when ureters are compressed by external malignant tumors or in benign strictures. This material has specific memory properties such that it exists in two states based on the temperature of fluid passing over it. This allows the surgeon to place the stents and pass warm saline to expand the proximal end of the stent to keep the stent in place. The Memokath stents have no proximal or distal coils and do not usually cause stent symptoms. They are ideal for

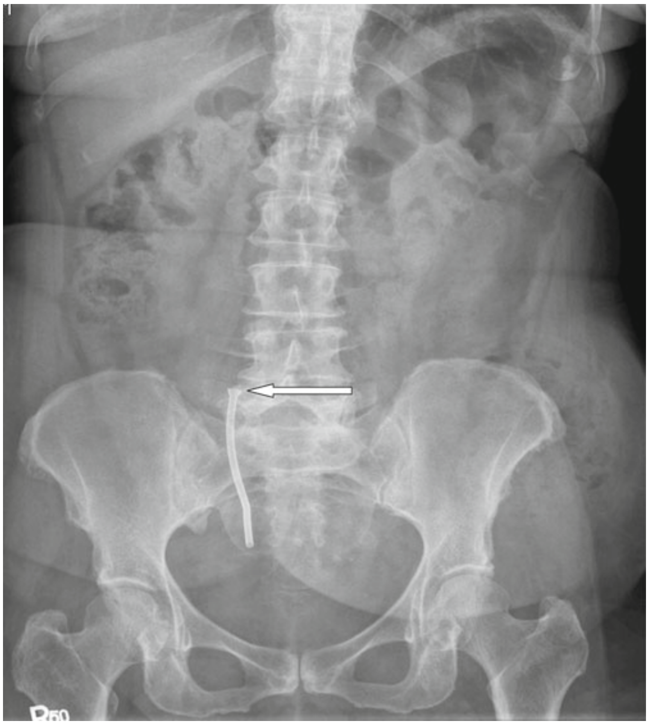

Fig. 60.10 A Memokath stent in situ. Note the expanded upper end holding it in place (*arrow*)

malignant compression and can usually last for 1–2 years or longer (Fig. 60.10). If used in benign cases, regular 6-month checks are required to ensure the stent remains in a good position and no blockage has occurred.

Other metallic devices are available and also made of nitinol that do not change shape at different temperatures. These devices are designed for longer term use. They do not rust or corrode, and tend to resist encrustation well, so are suited for long-term use. They tend to be uncomfortable, however; are more expensive; and are more difficult to place.

Conditions Suited to Ureteric Stent Insertion

The ureteric stent is used for three main purposes:

1. The relief of renal obstruction
2. To facilitate later passage of endoscopic equipment to the upper urinary tract in an unsafe ureter
3. To allow safe healing in a damaged ureter, either accidentally or deliberately

The Relief of Renal Obstruction

An obstructed kidney will cease to function as a filtering and detoxification unit within hours of an obstruction happening. Long-term obstruction may end in the destruction of the renal unit involved, and short-term obstruction associated with infection may become rapidly fatal.

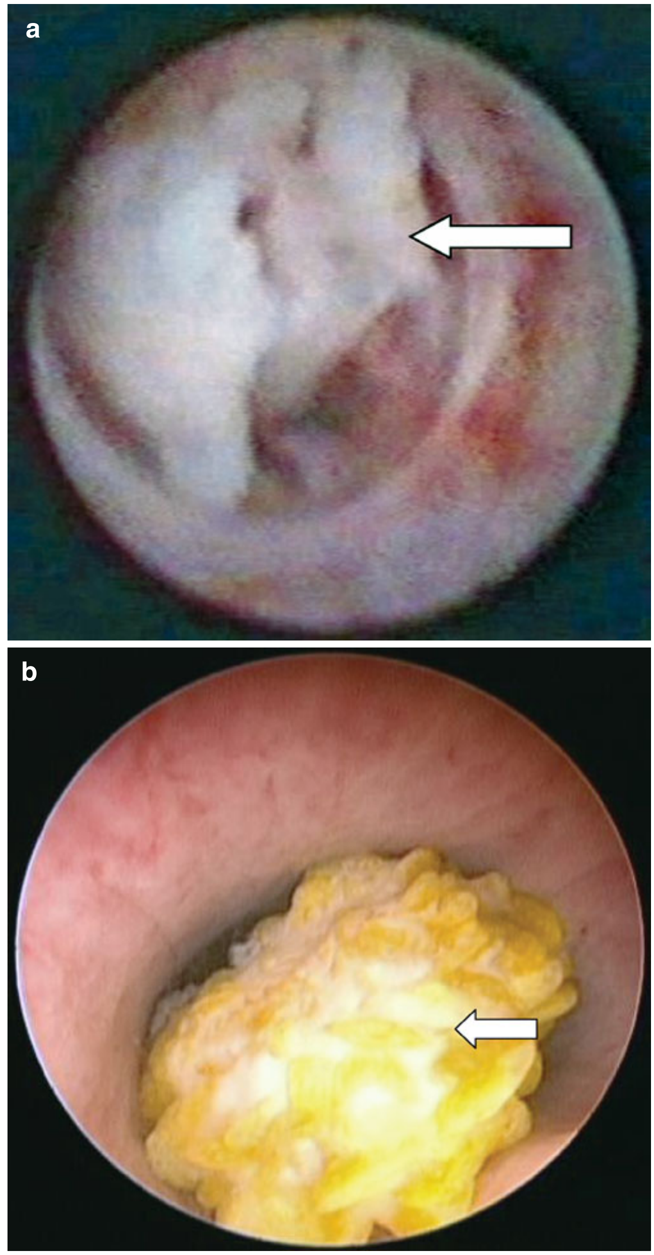

Fig. 60.11 (**a**) Endoscopic view of a ureteric tumor (*arrow*). (**b**) Endoscopic view of a ureteric stone (*arrow*)

Relief of such obstruction therefore is important in all but the most transient of causes. This may be best done by percutaneous drainage of the kidney (nephrostomy, antegrade stenting) or via a transurethral method (retrograde stenting). One must not overlook the lower tract as a cause of dilatation; an obstructing prostate or a failing bladder may lead to renal obstruction, which is best treated with a catheter. Also, kidneys may be dilated without obstruction, and as such in a situation of doubt, isotopic renography may be helpful.

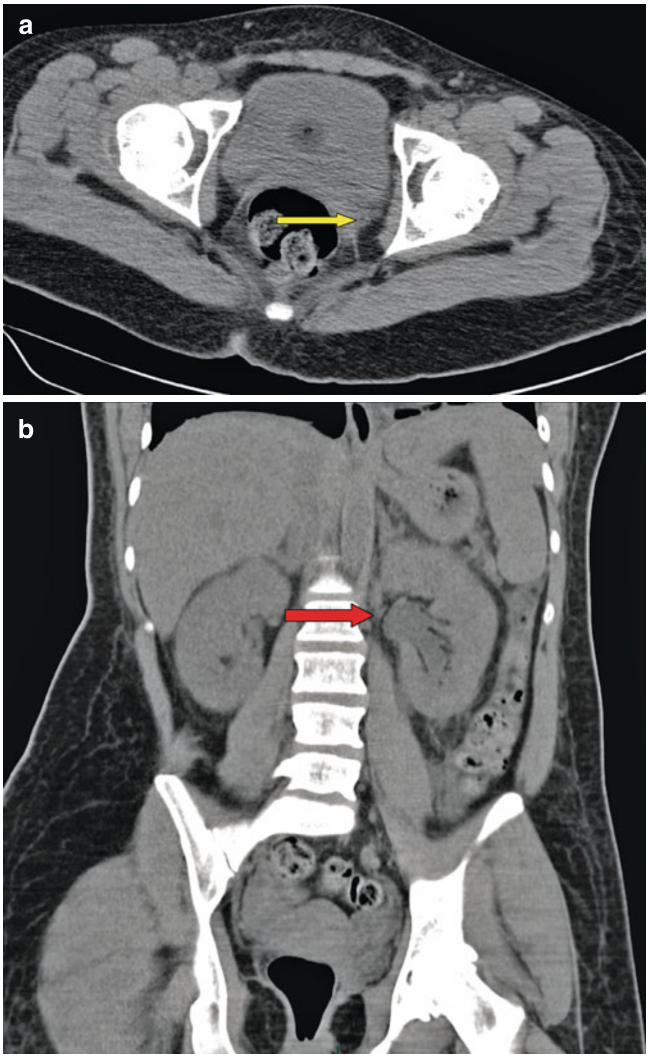

Fig. 60.12 Plain CT KUB showing (**a**) sloughed renal papilla (*yellow arrow*) leading to (**b**) pyonephrosis (*red arrow*)

Renal obstruction may be intraluminal, luminal, or extra-luminal:

1. Intraluminal
   (a) Stone (Fig. 60.11a, b)
   (b) Sloughed renal papilla (Fig. 60.12a, b)
   (c) Papillary transitional cell carcinoma (TCC) (Fig. 60.13)
2. Luminal
   (a) Stricture
   (b) Annular TCC
   (c) Pelviureteric junction (PUJ) obstruction (Fig. 60.14)
3. Extra-luminal
   (a) Tumor
   (b) Iatrogenic (clip or a stitch)
   (c) Procidentia, causing fish-hooking of the ureters

The commonest of these is the obstructing stone; one in ten men in the UK will develop a stone over their lifetimes, and

Fig. 60.13 Ureteric tumor (*green arrow*) causing obstruction of the left kidney on CT KUB

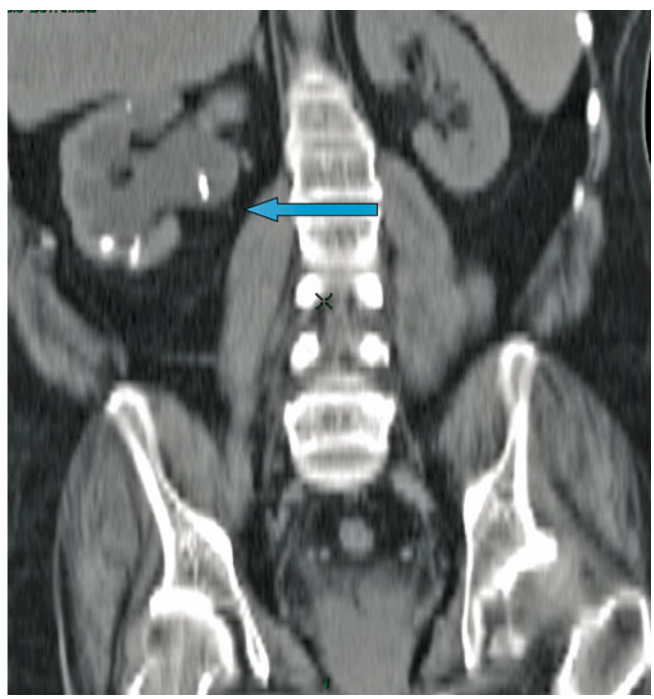

Fig. 60.14 PUJ obstruction (*blue arrow*) leading to renal obstruction and stone formation

these may be excruciatingly painful. Placement of a stent may aid pain relief and allow effective treatment of a stone at a later date while preserving renal function in the meantime.

To Facilitate Later Passage of Endoscopic Equipment to the Upper Urinary Tract in an Unsafe Ureter

Many centers especially treating stone disease find that patients will often need obstruction relieving in an acute setting, often in the late evening or middle of the night. It may be that specialist equipment or expertise is not available at this time or that it is simply not possible to treat the obstruction in one go. A stone may often have developed a significant tissue reaction, leading to a friable edematous ureter below it that bleeds easily. In these cases, a ureter may be "rested" for a number of weeks with a stent prior to a second look, which is often a technically easier exercise.

To Allow Safe Healing in a Damaged or Operated Ureter

Injured tubular structure tends to heal with scarring, and as this contracts, strictures may form. Repairing a ureter over a stent allows a more patent ureter as the stent acts like a scaffold, holding the ureter open as it heals. Ureteric and renal surgeons will often leave a stent after endoscopic surgery to allow easy passage of debris, and promote patent healing of the ureter.

Placing a Ureteric Stent

Basic Technique

Placing a ureteric stent can take a few minutes to perform. Likewise, it can also take several hours in a difficult ureter with an impacted stone, poor visibility, and a challenging lower tract. The key message is to assume the worst. There is no such situation as "just a ureteric stent"!

Two main methods will be discussed: placing a stent via a cystoscope and freehand stenting.

Cystoscopic Stenting Method

1. In a correctly prepared, consented, and draped patient in extended lithotomy position, introduce a cystoscope into the bladder (Fig. 60.15). Find the appropriate ureteric orifice (UO). The authors prefer to have both live fluoroscopy available and the most recent static images available in theater to check the appropriate side.
2. Cannulate the UO using the floppy tip of a guidewire (Fig. 60.16). It must be remembered that the wire will tend to exit the scope in a slight downward direction and the scope may need to be turned 90° away from the UO to facilitate passage. If the wire exits the scope unkindly so that it cannot be seen, pull the scope back to the bladder neck and reposition the wire. Occasionally taking the scope partly apart may help. If the wire does not sit in a comfortable viewing position, pass a ureteric catheter over the top to leave a few millimeters of the wire showing. The ureteric catheter will stiffen the wire allowing a better viewing position. It may also be used for retrograde pyelography if desired.
3. Run the guidewire up to the renal pelvis using image intensification. It is the authors' contention that placing the wire under continuous X-ray screening holds no benefit over static pictures and increases the radiological load to the patient. Inexperienced operators will often obtain a "road map" by obtaining a retrograde pyelogram first (Fig. 60.17). More experienced operators tend to use a mixture of tactile feedback from placing the guidewire, pattern recognition as to where the top of the wire is coiling, and judicious use of contrast when the wire or ureter are not behaving in the appropriate way or difficulty is encountered.
4. Slide the stent over the wire into the ureter, over the guidewire, through the cystoscope. Several maneuvers facilitate this. Ask an assistant to help slide the stent over the wire and then ask them to fix their end of the guidewire at a point, such as the patient's leg, so that it does not move as the stent moves. Many stents have one crosscut end and one tapered end. Make sure that the stent is introduced tapered end first into the cystoscope. Hold the scope close to the UO and watch it enter. It will usually go only slightly into the ureter as most of its length will lie within the scope (Fig. 60.18a, b). The authors will perform two exercises prior to inserting the stent: they remove the attached thread from the stent (which is used to remove the stent under local anesthetic in certain conditions) and will note the last mark on the stent before the lower pigtail to be placed.

Fig. 60.15 Pusher through a cystoscope. This will allow the surgeon to thread the guidewire through the scope if it has been left at the end of a procedure for stent insertion

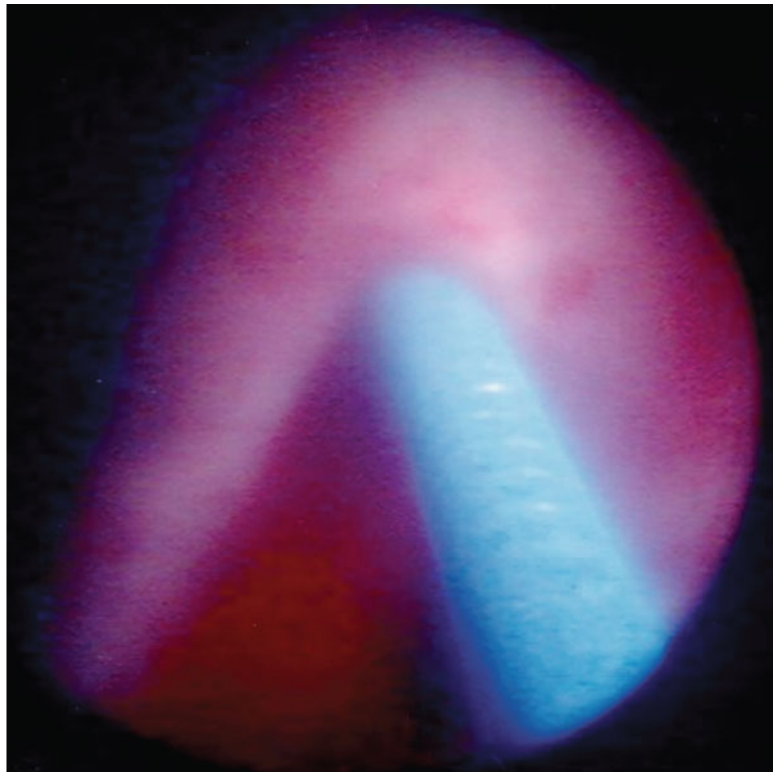

Fig. 60.16 Cannulation of the right ureteric orifice (UO) with a PTFE-coated guidewire

5. Slide the pusher over the guidewire. The wire should be fixed as in point 4 above. The authors tend to keep close to the UO until the noted mark is seen and then use X-ray to check the top end of the stent. Sometimes withdrawing the guidewire partially back facilitates the curling of the stent in the renal pelvis. With the top end of the stent correctly placed, the cystoscope is withdrawn to the bladder neck and the pusher gently advanced until its tip is seen (Fig. 60.19a, b). The guidewire is withdrawn until the stent can be seen to curl in the bladder.

Freehand Stent Placement Method

This is a more advanced technique and the authors would recommend being comfortable with the cystoscopic method before attempting a freehand stent placement (Fig. 60.20). We will usually place a stent through a cystoscope if we happen to be in this position when the stent needs to be placed or in a very difficult ureter with one precious wire that must not lose its position.

With a wire correctly placed into the renal pelvis on fluoroscopy, the stent is slid over the top of the wire as before. The authors prefer to use a stent pusher with a radiopaque marker at its tip. It is paramount that the wire is fixed so that it cannot move with the stent. This tends to leave a coil of wire in the bladder that will stop the stent entering the UO or even the wire to fall out.

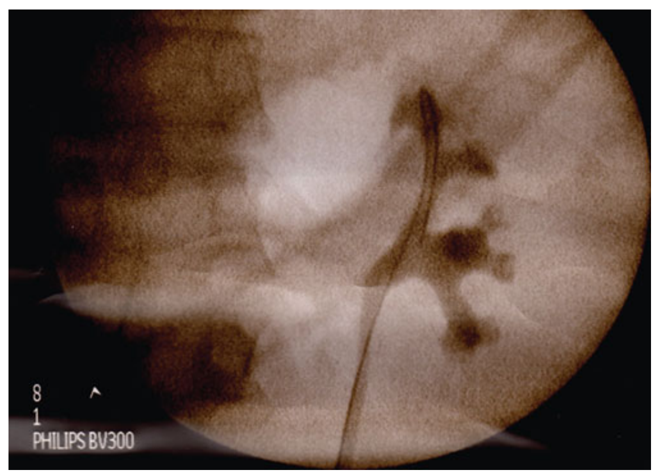

Fig. 60.17 Guidewire within the upper pole and renal pelvis on single shot X-ray. Retrograde study used to demonstrate anatomy

The stent is then positioned within the renal pelvis via the pusher, and the wire withdrawn into the upper ureter under fluoroscopy to assess correct coiling. The image intensifier is then placed over the bladder so that the pubic symphysis is seen, along with the bladder. The guidewire is then withdrawn under live screening until it can be seen within the bony pelvis, and the lower portion of the stent starts to move from a predominantly vertical lie to a more horizontal one. At this point, as the wire is withdrawn further, the pusher is pushed further into the bladder, tenting the stent up above the symphysis. It then springs off the

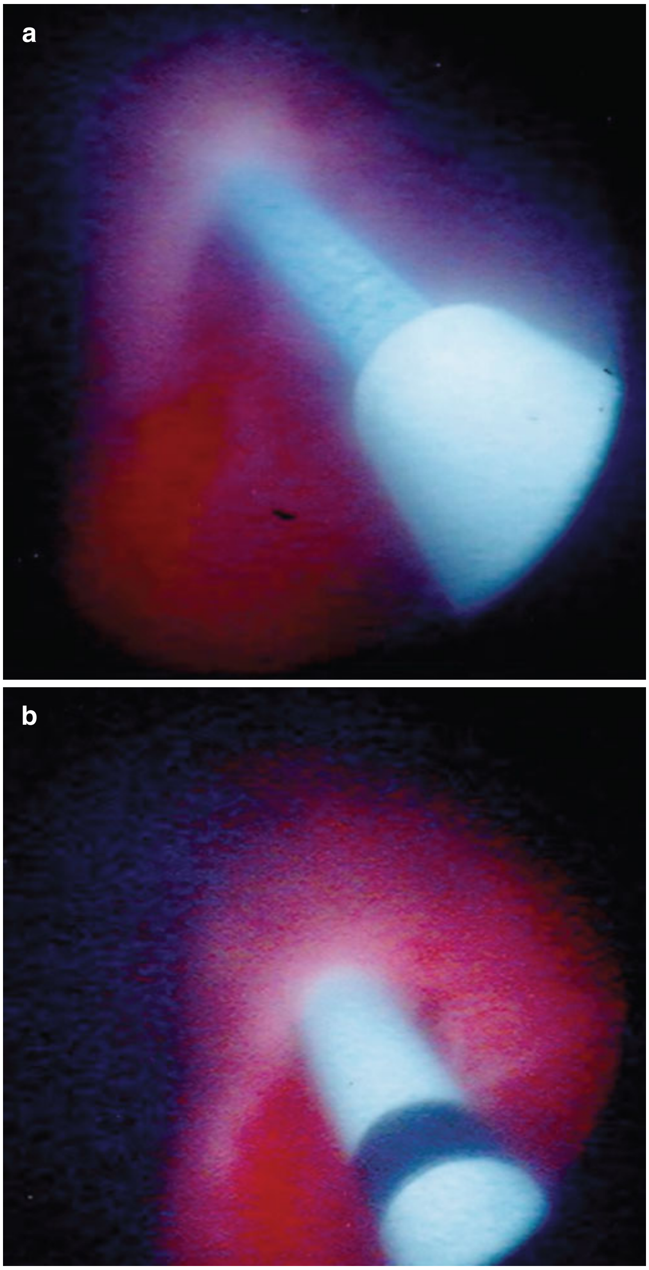

Fig. 60.18 (**a**) Stent seen sliding over guidewire toward OU and (**b**) then partially within the UO. Note the black distance marker

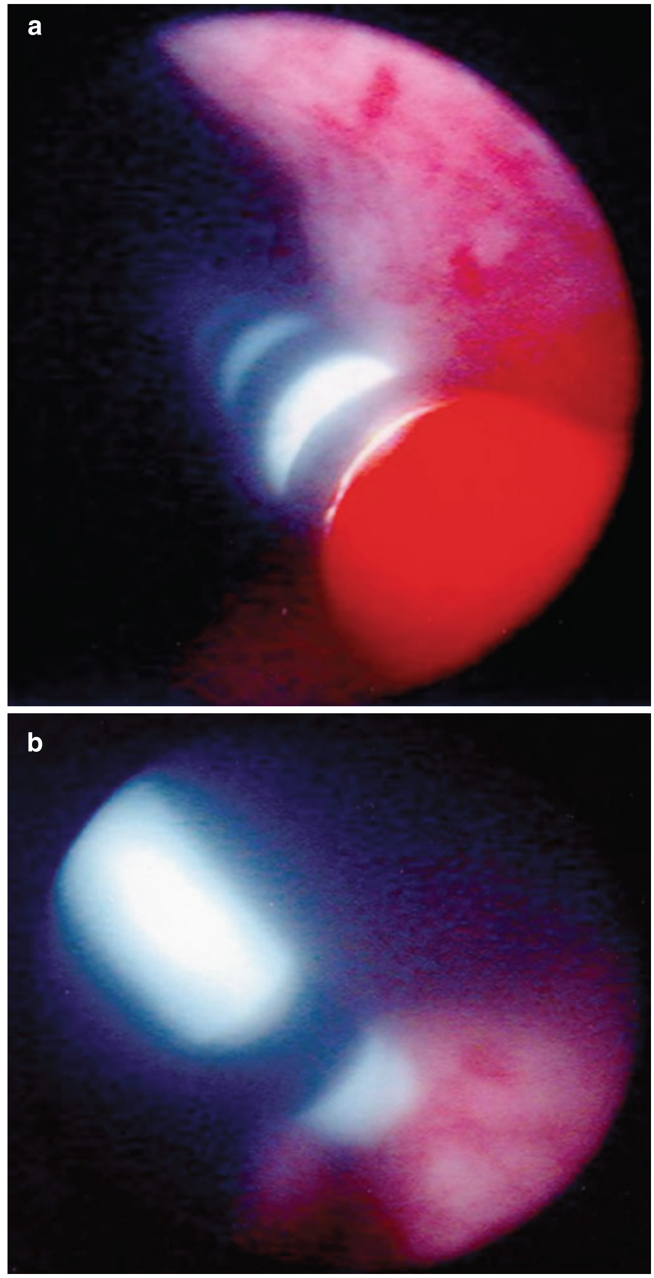

Fig. 60.19 (**a**) Pusher seen at end of stent over guide wire and (**b**) after withdrawal of pusher and wire

pusher as the wire is fully withdrawn, leaving the lower curl visible on fluoroscopy.

Antegrade Stent Placement

This may be performed by a radiologist but is a useful technique to be able to perform, especially for surgeons undertaking percutaneous nephrolithotomy. With a renal puncture performed, and a guidewire placed such that a large proportion sits coiled in the bladder, the stent is placed in an antegrade fashion so that the lower end crosses the midline on fluoroscopy. The wire is withdrawn with a holding pusher on the antegrade end of the stent to stop it from being pulled back out. Position is confirmed via fluoroscopy.

Troubleshooting

Several key factors may make an easy stent placement difficult. There are also several useful points that may make a difficult stent insertion easier.

Keeping an Easy Stent Insertion Easy

Several important points will aid in the insertion of a ureteric stent and promote success:

1. Keep the wire straight—wires coiled in the bladder will not accept a stent. It is best to check position using image intensification and pull back on the wire until it is straight and begin again rather than struggle with a curled wire.
2. Discard a bent wire—if you force a wire and it bends, it is better to begin again or perform a guidewire exchange (see later) than struggle on (Fig. 60.21). Wires work by transmitting the forward force applied at their base in a straight line, and this advantage is lost in a bent wire. Also, it is difficult to pass a bent wire through a cystoscope and very difficult to pass a stent over the bent portion of a wire.
3. Keep the wire fixed—if the wire is held such that it cannot move as the stent, pusher, or ureteric catheter is advanced, the overlying tube will move into position. If the wire is allowed to move, it has the opportunity to move sideways, resulting in coiling.
4. Use X-ray to check position—Think of X-ray as a car rearview mirror. This is used to check that what one has done is correct or if a difficulty has occurred.
5. Check the end marker before the stent is inserted and stay close to the UO—this will allow the operator confidence to insert the stent until the mark is reached.
6. If the stent is in the kidney and it is difficult to push the pusher in further, but the endpoint marker has not been reached, hold the pusher and withdraw the wire 5 cm. This may increase both the room for and the pliability of the stent in the kidney, making it easier to insert.

Making a Difficult Stent Insertion Easier

1. Assume difficulty—it is far better to enter a stent insertion expecting the worst. Keep to basic principles, be

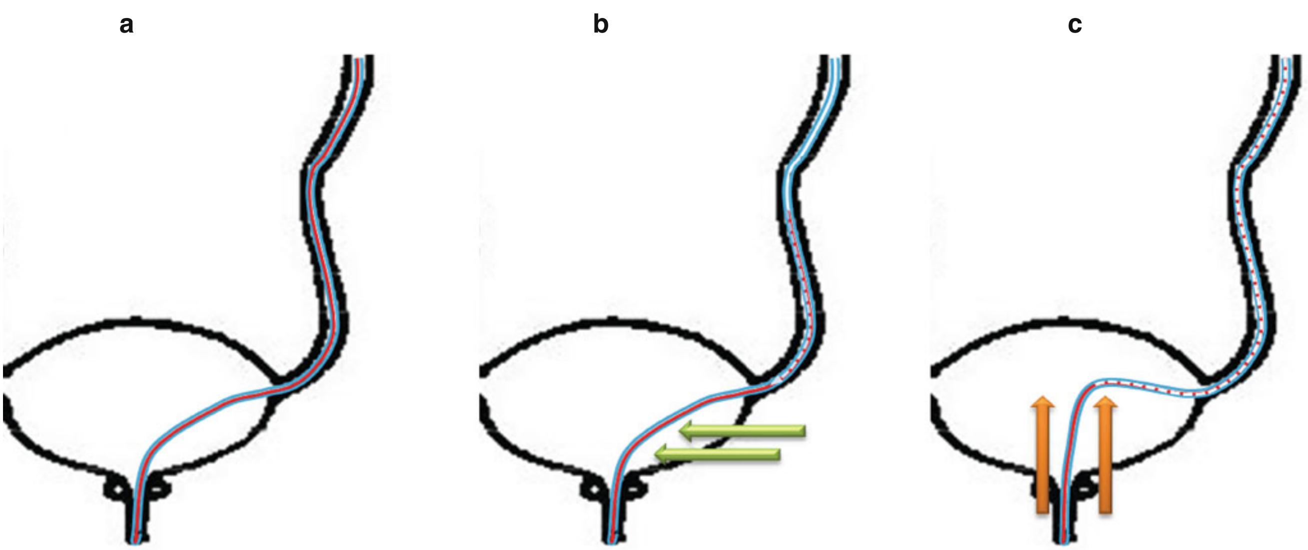

Fig. 60.20 Diagram showing the steps involved in hand stenting. (**a**) The stent (*blue*) contains the guidewire (*red*). As the wire is screened down the lower ureter, the stent moves from a relatively vertical to a more horizontal position (*green arrows*) (**b**). (**c**) At the same time the pusher pushes the stent into the bladder (*orange arrows*), and the wire is withdrawn further until the stent coils as normal within the bladder

Fig. 60.21 A bent guidewire. Throw it away

aware of complications, and be prepared to stop and consider alternatives such as a nephrostomy.

2. The wire will not go up the ureter—there are a number of reasons this may happen:
   (a) Something (i.e., the stone) is in the way.
   (b) The ureter is tortuous and dilated.
   (c) The wire is bent or coiled (see previous).

In the first two situations, it is worth the operator being wary. It is very easy to lose a precious wire that is partway placed or push a wire either through a suburothelial tunnel in the ureter or outside the ureter and make a difficult situation much worse.

The first maneuver to try is to use a hydrophilic floppy wire. These must be made wet before use and are difficult to handle. In placing them through a cystoscope, it is often useful to grasp them with a gauze swab. It is extremely easy to lose position with them or for them to fall out. Judicious use of fluoroscopy aids in checking position. The authors feel that it is unwise to place a stent over one of these wires, and as such, when correct position has been obtained, the wire should be exchanged with a standard guidewire. This can be achieved by passing a ureteric catheter over the top of the hydrophilic wire, removing the wire and placing a standard wire, or using a dual lumen catheter, preloaded with the standard wire.

In tortuous and dilated systems, a hydrophilic wire again may be helpful. Generally two factors help stent placement: having as much wire beyond a problem point so that it will not slip out and rotating the wire so that the ureter straightens. Occasionally, live screening may help this maneuver. It cannot be emphasized enough that a straight wire will always allow an easier stent insertion than a curved one. If the wire will not straighten, introduce a ureteric catheter over the top of the wire to stiffen it and keep it straight. This allows more accurate work at points of difficulty. If this is unhelpful, it may be necessary to pass a ureteroscope.

With a difficult obstruction, such as impacted stone, it may be useful if a hydrophilic wire will not pass, to look under direct vision using a small ureteroscope. While the authors will often manage a ureteric stone with a primary ureteroscopy, it is not often possible in all cases, especially if infection is suspected or present. Nevertheless, if a stent will not pass an obstruction, it is better to introduce a small ureteroscope and visually try to pass a wire past the obstruction using fluoroscopy to confirm position. If a wire has been passed out of the ureter or into a suburothelial tunnel, leave it in place and return with a ureteroscope and a fresh wire and try in a different position. The first wire will occlude the hole made and reduce extravasation. Extreme care needs to be taken in ureteroscopic techniques; the ureter may be extremely friable and may avulse very easily. If all techniques fail, it is by far safer to pull out and insert a nephrostomy, with subsequent antegrade stent insertion than to pursue a difficult and worsening situation in a retrograde fashion.

The Lost Stent

It is very possible, especially by an inexperienced freehand stent inserter to lose the stent into the lower ureter. In this situation, a ureteroscope should be passed into the lower ureter and ureteroscopic graspers or baskets used to manipulate the stent back into the bladder. If this fails, a percutaneous antegrade approach may be needed first to temporize the situation and to subsequently remove the stent.

Encrustation

Basic Concepts

Encrustation is a multifactorial process that occurs on a great many surfaces. Its effects are significant not only for medicine in general, and for urology in particular, but also in the fermentation industry, in gas turbines, and in many other industrial processes. In the medical sphere, encrustation or sludging can happen in respect to other stents, such as those used in coronary arteries and the biliary tree, and may also affect other implants, such as orthopedic prostheses, intraocular implants, and ventricular shunts. Encrustation often necessitates changing or altering the device in some way, involving operations or further procedures for the patient, which have attendant risks of mortality and morbidity.

Dental plaque is a common form of crusting that is thought to be deposited in a similar way to urological encrustation. Both processes involve the position of a basic conditioning film, which may or may not be followed by bacterial events, but eventually salts and other compounds are deposited on the surface forming a crust. In dentistry such a crust is called plaque and is removed by brushing or by a visit to a dental practitioner. In urological practice, encrustation may affect any device that lies in contact with urine, i.e., at least in part above the bladder outflow sphincter, and this usually necessitates removing the device and replacing it with a new one.

Bacterial Biofilm and Its Role in Encrustation

Overview

There is much debate in microbiological, industrial, medical, and surface science circles as to the contribution that bacteria give to encrustation. It is certainly true that bacteria are not essential to cause encrustation on a ureteric stent. However, most, if not all, stents had associated bacteria on the surface after removal. These bacteria are not in the standard "planktonic" or free form. They have properties that would promote encrustation, such as causing changes of pH to their microenvironment and their ability to secrete extracellular polymeric substances.

The association between urinary infection and stone formation was first recognized by Horton Smith in 1897 [8] and Brown in 1901 [9]. However at this time, the pathogenesis of stone formation and calculus structure was not understood, and the role of urease-producing organisms was also not appreciated.

Putative Steps in Biofilm Formation and Encrustation

A number of steps have been proposed:

1. Absorption of proteins and other urinary constituents onto the device surface to form a conditioning film due to interaction between electrostatic forces of these urinary constituents and the device itself.
2. Weak attachment of planktonic bacteria to the device surface by a similar process of electrostatic attraction. This process is promoted by the presence of the conditioning film.
3. Genetic upregulation in the bacteria leading to ultrastructural changes.
4. Strong attachment of the bacteria to the device.
5. Production of extracellular polymeric substances (EPS).
6. Bacteria-community interactions, communication, and turnover, as explained later. This includes production of enzymes such as urease.
7. Splitting of urea by urease causing an increased local pH, leading to salting out of calcium and magnesium salts from solution. These salts are then deposited onto the device surface as a layer of encrustation.

Bacterial Activity and Its Role in Encrustation

The bacterial composition associated with ureteric stents is usually a monoculture; this will usually take the form of *Proteus mirabilis*. *Proteus mirabilis* produces the enzyme urease that causes the hydrolysis of urea. The resultant reaction yields NH_4^+ and OH^- ions.

The urine pH rises and the newly generated NH_4^+ ions are available for the formation of struvite crystals. The alkaline environment also increases the formation of CO_3^{2-} ions from CO_2, which are available for calcium carbonate crystal formation. In addition, a high pH increases the formation of PO_4^{3-} and HPO_4^{2-}, which are able to generate calcium phosphate crystals. Urine is supersaturated with many of these ions, and the extra crystal load is readily deposited on the device surface.

Strategies to Combat Biofilm

Antibiotics are commonly given up to the time of surgical implantation. The evidence for their usefulness is, however, not convincing. In one study, 12,000 times the dose of gentamicin was required to kill the biofilm on a device in vitro compared to that required for free bacteria. This resistance is thought to be due to the conformational changes that occur during genetic upregulation. Changes in protein coats of the bacterial cell wall are thought to inhibit penetration and render standard antibiotic modalities ineffective.

There has been some effort to bind antibiotics onto devices. One major problem is that antibiotics bound to a device's surface tend to release their load rapidly so that only for a short time the effective concentration is reached. One of the aims of this thesis is to examine the timing of biofilm formation and to see whether antibiotics would have a role in preventing encrustation.

The next modality of prevention of device-related infection is the modification of biopolymers. Much work done in this area has been at the instigation of device manufacturers. Various chemical or physical modifications intended to change properties such as surface free energy charge and surface roughness have been devised, but none has yet been of clinical benefit. One of the major problems is that surfaces are coated by conditioning films rapidly and this tends to obliterate many modified surfaces.

Metal coatings, especially silver, have been used extensively. Results tend to be good in vitro but animal and clinical studies do not support the findings. Coatings including silver tend to have two main problems: the first is that the glycoproteins in the conditioning film tend to interact with the coating, and secondly, once in contact with urine, the metal ions are rapidly eluted. There is some evidence that impregnation of the polymer matrix with physicochemically compatible antimicrobials rather than layering them on the surface may yield promising results.

Health Economics of Urinary Encrustation

The most common devices placed within the urinary tract are urethral catheters and ureteric stents. It has been estimated that 28 % of all patients in chronic care facilities require indwelling urinary catheters. Fifty percent of patients with a long-term indwelling catheter suffer regular encrustation and catheter blockage. The great majority of patients with a catheter in situ are elderly and accounts for 4 % of the community nursing caseload. It is impossible to predict which patients will suffer from catheter blockage, and an individual patient may at some time experience catheter blockage and at other times will not.

Encrustation and catheter blockage can be extremely distressing and often lead to an episode in accident and emergency, which can be costly for the National Health System (NHS) and also very inconvenient to the patient. It has been estimated that the district nurse commitment to urethral catheters is about 500 h/month or 1,000 visits per year in a district with a total population of 500,000. Furthermore, changing a male urethral catheter requires a skill that requires training and is not necessarily a prerequisite for district nursing.

Catheter Blockage Symptoms

When a catheter blocks, it ceases to function as a drainage device (Fig. 60.22). The bladder will fill to a maximum amount, causing pain. As the bladder reaches its elastic limit, and as encrustation irritates the bladder wall, strong, often painful, bladder contractions force urine around the sides of the catheter. This is known as bypassing and leaves the patient wet and uncomfortable.

As the encrustation rubs on the bladder wall, it may also cause bleeding. Symptoms are often considered to be caused by infection, but this is not always the case. Bacteria associated with the device surface, a biofilm, are not necessarily susceptible to antibiotics and do not cause a conventional cystitis. Device removal and placement of a new catheter is the best form of treatment. Another problem is that a piece of encrustation may fall off into the bladder and become a nidus for bladder stone formation.

On occasions, patients may need hospitalization, with its attendant risks of morbidity and mortality. Changing the catheter increases the risk of infection and septicemia, due to trauma and introduction of urinary pathogens into the bloodstream.

Fig. 60.22 An encrusted and blocked catheter

Ureteric Stents

Ureteric stents suffer from similar problems. While many stents are placed for the short term, severe encrustation and stone formation has been reported, but there are instances of neglected stents that have not encrusted. It is impossible to predict who will have problems with encrustation and who will not. However, encrustation will limit the useful lifespan of a ureteric stent. At present, all stents are licensed for a maximum of 6 months within a patient, but some devices may soon gain licenses for a year. The important point is that a stent that can be left in a patient for a longer time reduces the number of replacement sessions, thus lowering morbidity and mortality associated with operative events, as well as reducing bed usage and hospital time.

It has been estimated that an improved urological device, able to remain within the body for 12 months rather than 6, by reducing encrustation and urinary tract infection, would save approximately €1 billion annually in health care spending in the European Union and a similar amount in North America. It remains clear that finding a solution to this problem is important.

The Lost or Neglected Stent

Stents can become, from time to time, lost (Fig. 60.23). Various methods have been employed to avoid this difficult situation, but all methods (stent registers, email alerts, on the day booking of removal, etc.) have their limitations. Some patients default follow-up for various reasons, and

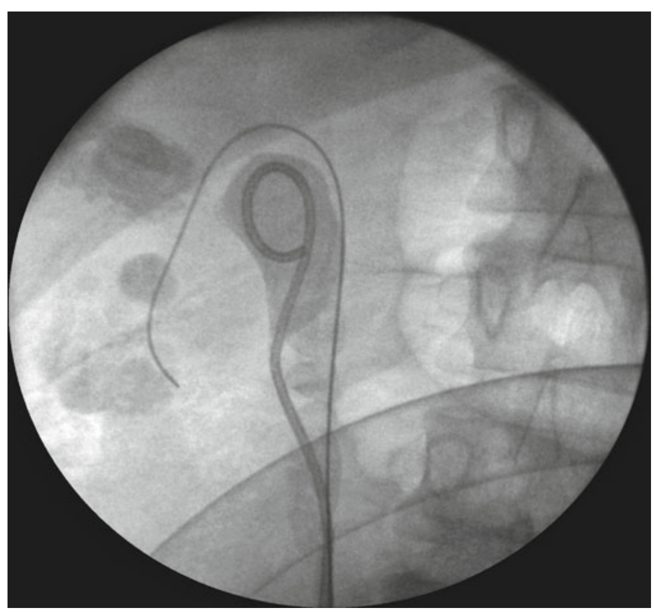

Fig. 60.23 Intraoperative pictures showing the upper coil and associated encrustation on a stent lost for 2 years

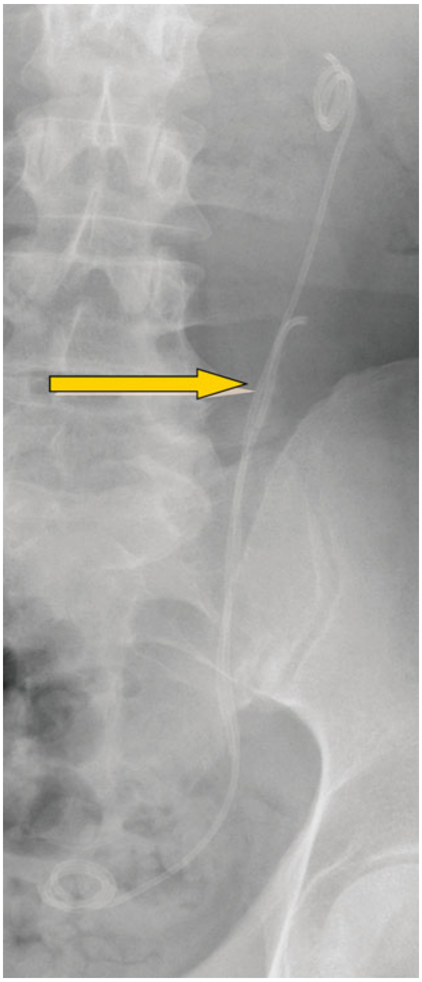

Fig. 60.24 Close up of a system containing a ureteric stent and a broken portion of a stent (*orange arrow*)

booking follow-up can be missed. Four scenarios can be encountered:

1. The pristine stent—this is rare and should be treated with suspicion. Stents immersed in urine for long periods of time become brittle (see scenario 2), and encrustation may not be so evident on a plain radiograph. Such stents should be screened out in theater under fluoroscopic guidance.
2. The brittle stent—again, these should be remove under live screening, with a full complement of ureteroscopes, wires, and baskets available if the stent fractures (Fig. 60.24). All pieces of a broken stent should be removed as they form a nidus of stone formation.
3. The encrusted stent—encrusted stents may uncoil when screened out, but may well not. The standard practice is to attempt to pass a ureteroscope alongside the stent and remove encrustation using a laser or a lithoclast. If this fails, percutaneous treatment is needed. Careful consideration is needed to decide on replacing the stent.

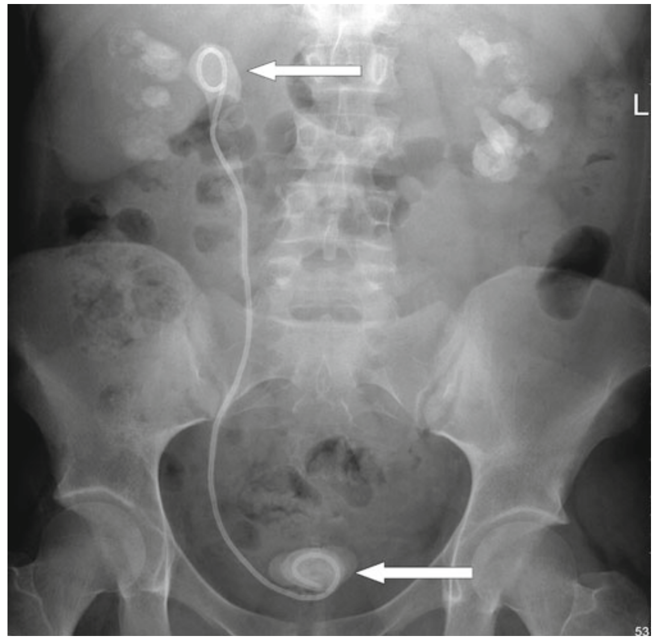

Fig. 60.25 Plain KUB demonstrating bilateral stones and a neglected stent with significant encrustation affecting the upper and lower coils (*arrows*)

4. The heavily encrusted stent—these are often too difficult to be treated in a retrograde pattern and need percutaneous management (Fig. 60.25).

Knotted Stents

Stents can catch their upper coil within itself (Fig. 60.26), and this may stop the stent from being removed. If a wire can be passed through the middle of the stent, then this will uncurl it and the stent can be screened out. If this is not possible, the authors tend to pass a ureteroscope to help uncurl the stent. By pinning the end of the stent, it may be possible to allow it to unravel. If this fails, percutaneous management is needed.

Conclusion

The Ideal Ureteric Stent

The ideal stent has not yet been discovered, but we have a fair idea of what it should be like. It should be easy to place, should be comfortable for the patient, can be inserted or replaced using the minimum of anesthesia and analgesia, can resist encrustation and loss of elasticity, and should allow excellent flow in an antegrade fashion, while resisting flow in a retrograde fashion. We are not there yet, but advances continue to be made toward this ideal.

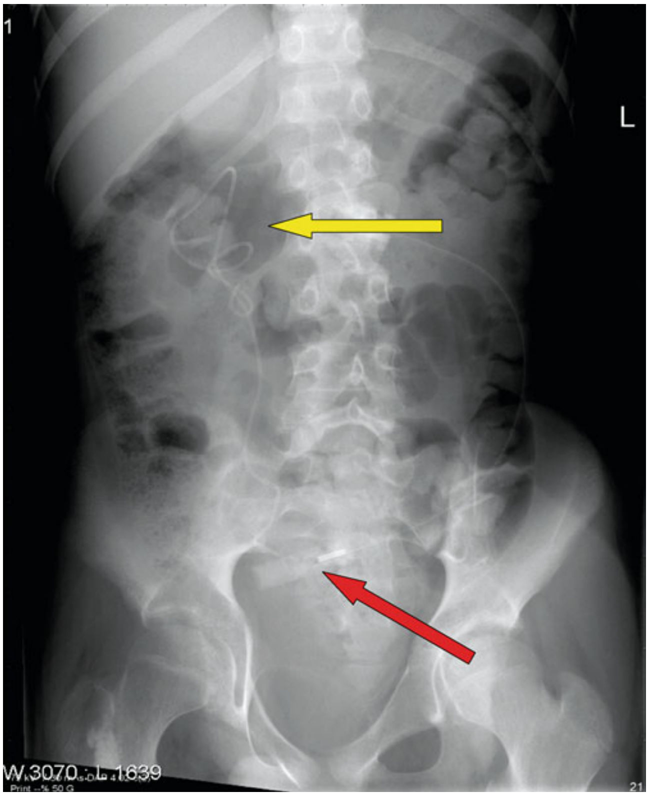

Fig. 60.26 A knotted stent. Note the large amount of coil in the kidney (*yellow arrow*) and the lower end has retracted into the ureter (*red arrow*)

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