Ureteric Stents

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Abstract

The ureteric stent is one of the most common urological prosthesis and is used in the management of ureteric obstruction along with reconstructive procedures involving the kidney, ureter and bladder. Stents are composed of synthetic polymeric biomaterials that must remain stable in an unstable chemical environment within the urinary tract. Although there have been many improvements in the design and functionality of stents, the search for an ideal stent continues.

Keywords

Ureteric stent • Urological prosthesis • Ureteric obstruction

Introduction

The ureteric stent is the commonest prosthesis used to manage ureteric obstruction secondary to both benign or malignant causes. It is also used in reconstructive surgery to maintain the patency of an anastomosis either between the two segments of the ureter or between ureter and other viscera such as bowel and bladder. Despite the evolution in design and biomaterials over the years, the ideal ureteric stent has yet to be developed. This chapter will provide an overview of the history and development of the ureteric stent and the different types of stents available for urological procedures.

History of the Ureteric Stent

The widely used double 'J' stent was first introduced by Finney in 1978. However, different types of ureteric stents have been described prior to this, with some dating back to the 1800s. Dr Gustav Simon is credited with performing the first ureteric stenting during open bladder surgery.

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The early stents dating back to the 1900s, were made from fabric coated in lacquer varnish. It was in 1967 that endoscopic insertion was introduced by Dr Paul Zimkind who placed a straight silicone prosthesis as a ureteric splint. McCullough devised the 'shepherd's crook' stent in 1974 with the aim of ensuring that the stent remained in a better position within the urinary tract [1]. Recently, modifications have focused on composition, patients' comfort and the longevity of the stents.

Stent Function and Physiology

The ideal ureteric stent should relieve intra/extra-luminal obstruction, be easily inserted, be radiopaque, resist encrustation or infection, avoid migration, be affordable and cause minimal discomfort to the patient [2]. Hollow ureteric stents are intended to allow drainage of urine through and around the stent [2]. The normal flow rate of urine in an unobstructed ureter is 0.5 ml/min, although it may be as high as 4 ml/min in patients with diabetes insipidus [3]. The presence of a stent reduces the urine flow rate by inhibiting ureteric peristalsis which results in a paralytic effect [4]. This loss of active propulsion also results in impaired transit of stones or stone fragments. Thus any movement within the ureter predominantly occurs due to a combination of ureteric dilatation and the effect of gravity [5]. This is highlighted by a study comparing the effects of stenting on the stone free rate after extra corporeal shock-wave lithotripsy (ESWL) for ureteric stones. In this particular study the authors concluded that there was a significantly higher stone free rate in patients without a stent compared to those with a stent. (89.9 % versus 81.3 %) [6].

Whilst some investigators have shown no difference in urine flow rates, with urine outputs of up to 100 ml/h achieved between commercially available stents, the composition of the stent does appear to be important [7]. A softer stent is easily kinked resulting in a slower flow and high pressures within the ureter regardless of the stent diameter. A harder stent has better drainage with less risk of kinking, but is found to be more uncomfortable for the patient and has the additional risk of ureteric ischaemia and erosion [8]. Stoller et al. reported an *in vitro* study proposing that urine flow and stone propulsion is greater with the use of a helically ridged stent when compared to a smooth stent. As most fragments of stone pass in the space between the stent and the ureteric wall, a spiral ridged stent not only optimises this but also allows most of the urine to travel around the stent. In instances of external compression, the helical stent is not as easily compressed and also allows urine to flow through the lumen [5]. It is important to remember that the rate of urine flow is also affected by additional patient related factors other than those mentioned above. These include the intrarenal pressure, intra-vesical pressure and urine density amongst others.

Indications for Stent Insertion

The main indications and contraindications to ureteric stenting are shown in Table 9.1.

Since its inception, ureteric stenting has played an adjunctive role to endoscopic stone surgery. This is to prevent post-operative mucosal oedema and residual stone fragments obstructing the ureteric lumen and causing renal colic. Due to the potential morbidity related to the ureteric stents themselves, the risk-benefit question 'to stent or not to stent?' should be considered.

Rane et al. studied 42 patients following elective ureteroscopy combined with lithoclast fragmentation for 6–10 mm ureteric stones. Follow-up at 24 h and 1 week showed that 55 % of patients had no post-operative discomfort, 38 % had some discomfort, and 7 % required parenteral analgesia. Only 1 patient had to be re-admitted with loin pain and 2 patients experienced discomfort at 1 week. The study concluded that routine stenting following elective stone treatment was not necessary in this subset of patients [9].

Another prospective randomised control trial by Denstedt et al. in 2001 included 58 comparable patients following routine ureteroscopy and laser fragmentation. They were randomised after stone fragmentation to a stent versus no stent

Table 9.1 Indications and contraindications to ureteric stenting [8]

Indications:	
	Intrinsic ureteric obstruction
	Benign – stones, stricture, congenital obstruction, PUJ obstruction
	Malignant – transitional cell carcinoma
	External ureteric obstruction
	Benign – retroperitoneal fibrosis, aortic aneurysm, endometriosis
	Malignant – Colorectal/gynaecological/lymphoma/bladder and prostate cancer
	Prophylactic
	Post ureteroscopy with or without stone fragmentation
	Protect ureteric anastomosis – renal transplant/pyeloplasty/ureteric injury
	Intraoperative ureter identification – complex abdominal/pelvic surgery
	Prior to chemotherapy/radiotherapy
Contraindications:	
	Infected, obstructed kidney in an unstable patient
	Relative contraindication: Urine production <400 ml/day – high risk of encrustation

group. Those in the stent group had the stent removed at 1 week post-operatively. Follow-up was at 1, 6 and 12 weeks. Their results showed that at 1 week, the symptoms of flank pain, abdominal pain, dysuria and frequency were greater in the stented group. At 6 and 12 weeks no difference in the pain or analgesic requirements were seen. Only 1 patient was admitted with urinary sepsis in the stented group and 1 patient was admitted with vomiting in the non-stented group. The stone free rate was still 100 %. They concluded that patients with stents have significantly greater symptoms with no difference in complications or stone free rates and suggested that routine stenting is not recommended after uncomplicated surgery [10].

Types of Ureteric Stents

Ureteric stents are available in many shapes, sizes and biomaterials. Classically the double 'J' stent is used routinely but not all stents are either coiled or hollow. Stents without side holes have been shown to drain 40–50 % less efficiently than those with side holes [4].

Stents can be broadly classified into:

(a) Non-metallic stents
(b) Metallic stents

Non-metallic Stents

Stent Properties and Biomaterials

Ureteric stents are composed of synthetic polymeric biomaterials that must remain stable in the unstable chemical environment within the urinary tract [11]. Additionally the design must follow certain basic principles that provide the parameters for optimal stent function. Some of these parameters are summarised in Table 9.2 below [12–14].

Non-metallic stents can be either synthetic or biodegradable. The most common synthetic polymer currently used is polyurethane. Whilst silicone is more chemically inert, the inherent rigidity results in more patient discomfort. The alternative biodegradable stents must maintain integrity for at least 48 h before beginning to disintegrate spontaneously. They do not require a second procedure to be removed from the ureter and can only be used for short term purposes [15]. Lingeman et al. describe a biodegradable temporary ureteral drainage stent (TUDS). The safety and effectiveness of the stent was defined as adequate intervention-free drainage for 48 h without stent migration. The stent was effective in 78.2 % of the 88 patients in the study population with a satisfaction rate of 89 % [16]. Research into long term biodegradable ureteric prostheses is still underway.

Table 9.2 Stent properties influencing stent design & function [12–14]

Stent property	Comment
Biodurable	The resilience of a stent to disintegrating in the urine's chemical environment.
	The latest generation of biodegradable stents however, are designed to be less resilient. They biodegrade within the urinary tract after a specific length of time so that they do not require removal as a separate procedure.
Biocompatible	The effect of the stent on its environment. Stents should be chemically 'inert' and elicit a minimal inflammatory reaction.
Encrustation	Despite stent coatings designed to resist encrustation, this can be a significant problem particularly in stone patients. Silicone coated stents are particularly prone to encrustation.
Coefficient of friction	The ease with which a stent can be inserted into the urinary tract without friction.
Memory	Refers to the ability of a JJ stent to spontaneously curl when deployed and remain as that shape. A coil strength memory of 20 g prevents stent migration [12].
Radiopaque	Stent walls contain metal salts which allow radiological visualisation
Diameter	The ratio between the inner and outer diameter of the stent determines the urine flow as well as the tensile strength. The larger the internal diameter the greater the potential for flow.
Cost	As a widely used prosthesis requiring frequent changes, stents must be cost-effective

Metallic Stents

Due to their rigidity and discomfort, metallic stents are usually reserved for upper tract extrinsic obstruction in cases of advanced malignancy. Their use in stone disease is not recommended and they appear less effective for intrinsic obstruction. They are thought to have a longer lifespan and thus can be left *in-situ* for a longer time period. In general, the metallic stent provides an alternative to the use of two simultaneous double J stents in patients with extrinsic compression and frequent stent blockages [17]. Dual ureteric stents have also been successfully described and are more appropriate in selective patients [18].

Kulkarni and Bellamy described a 4 year follow-up study of their experience with a self expanding nickel-titanium Memokath ureteric stent. This stent has a thermal memory for shape and is used for both benign and malignant ureteric strictures. The expanded proximal fluted end holds the stent in position across the stricture (See Fig. 9.1). As the stent softens at low temperatures, it must be cooled to below 10 °C by irrigating cold water in order to allow stent removal. Of the 37 stents inserted since 1996, all bar 2 achieved upper tract decompression. The unsuccessful cases underwent replacement using stents which had a better length. Stent migration occurred in three patients after treatment of the underlying malignancy. Although upper tract decompression was maintained, the stents were replaced to relieve irritative urinary symptoms from malpositioning of the stent. There were no reports of stent encrustation or hospital attendance due to stent symptoms, sepsis or haematuria [19].

Ureteric Stent Design

A number of stents are currently available. The common ureteric stent designs are summarised in Fig. 9.1 [20–29].

Symptoms Related to Ureteric Stents

The morbidity associated with stent insertion is all too familiar. Patients often complain of general loin discomfort and experience irritative lower urinary tract symptoms (LUTS). Loin pain has often been attributed to reflux of urine the ureteric stent and has been documented in 79 % of stents [30]. Pressure flow studies have shown equal pressure transmission from the bladder to the renal pelvis in all phases of bladder filling and emptying which partly accounts for the loin pain [31]. This *in vivo* study concluded that stent insertion should be for the minimum duration required within

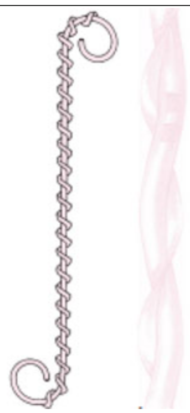
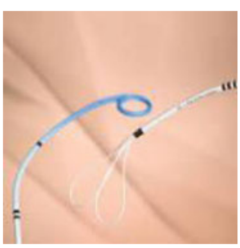
Non-metallic stents	
	**Double J stent** Standard ureteric stent.
	**Multi length stent [22]** Multiple curls allow accommodation of stent within ureters and is 22–30 cm in length.
	**Grooved stent [23]** Made of Tecoflex® material, softens at body temperature to minimise patient discomfort. Aims to encourage urine drainage around stent.
	**Spiral stent [4]** Developed for increased extraluminal drainage in particular for chronic external ureteric compression.
	**Dual durometer stent [24]** Dual Durometer Percuflex™ Stent with HydroPlus™ coating featuring a novel bladder loop design. Made up of two biomaterials. A firm material is used at the renal end and a softer one at the bladder end in order to reduce stent symptoms.

Fig. 9.1 Common ureteric stent designs

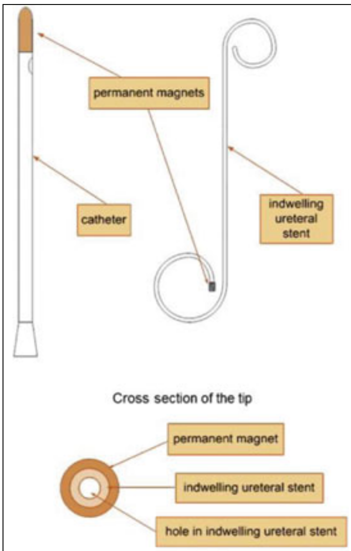
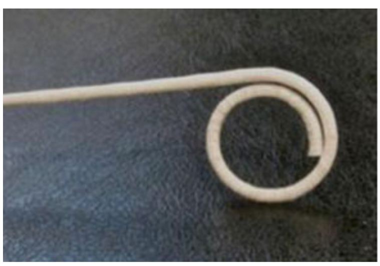
	**Magnetic tip stent [25,26]** Ureteric stent retrieval without the need for cystoscopy.
	**Biodegradable stents [27]** **Uriprene™** Radiopaque, glycolic-lactic acid Degrades starting distally and degradation continues proximally which prevents ureteric obstruction from the degraded fragments and also minimises bladder irritation.
Metallic stents	

Fig. 9.1 (continued)

	**Double J stent [28]** **Resonance®** Nickel-cobalt-chromium-molybdenium alloy. Tightly coiled metal wire. Firm and ideal for external ureteric compression.
	**Double J stent [29]** **Passage™** Gold plated metal (Snake stent) Spiral windings along tubular coil structure and flexible pigtails
	**Double J stent [30]** **Silhouette®** Polyurethane and metal wire coil reinforcement

	**Self expanding** **mesh stent [31]** Large bore stents, 24Fr–30Fr, made of a super elastic alloy covered by a polymeric material for preventing tissue in growth. Useful in chronic ureteric strictures.
	**Self expanding** **Memokath® 051 [18,20]** Self expandable nickel-titanium stent.

Fig. 9.1 (continued)

sterile urine which prevents long-term renal parenchymal damage and avoids the morbidity associated with urosepsis [32].

Joshi et al. presented the first validated symptom assessment tool for patients with a ureteric stent by using the ureteral stent symptom questionnaire (USSQ) and EuroQol as assessment tools. The USSQ is a validated psychometric measure of stent symptoms and quality of life (QoL). The various domains include urinary symptoms, pain, general health, work performance and sexual health. Patients were subdivided into those with stents from healthy controls and those with a stone but no stent. The EuroQol is a QoL questionnaire with a visual analogue score which looks at holistic physical, emotional and social health of the patient. The results from studies using the EuroQol showed a cumulative effect of symptoms and a significant negative impact on health related QoL in those patients with a stent. The authors conclude the need for an improvement in stent design together with preoperative patient counselling. However, the limitations of this study included the use of only one type of stent, limited/unequal patient group numbers and the use of a relatively complex questionnaire [33].

A further meta-analysis has looked at the possible beneficial effects of alpha blockers on stent related discomfort and symptoms [34]. From a total of five studies, 461 patients were identified for inclusion into the meta-analysis having received the alpha blockers, tamsulosin or alfuzosin or placebo and the results suggest, that alpha blockers can help relieve stent symptoms and discomfort [34].

A randomised controlled trial by Dellis et al. also confirmed the above findings in 150 consecutive patients undergoing insertion of a double 'J' stent who were randomised to either tamsulosin, alfuzosin or placebo. The USSQ was completed at week 1 and 4 after insertion of the stent and again 4 weeks after stent removal. There was less pain, LUTS and impairment to general/sexual health in those taking the alpha-blockers with no difference between tamsulosin or alfuzosin [35].

Complications

The most common ureteric stent complications are summarised below (Table 9.3).

The Forgotten Stent

Despite the increasing use of stent registers, the system is by no means robust and stents are still left within the urinary tract for prolonged periods of time. The potential morbidity, mortality and legal implications as a result of these forgotten stents is well documented [36, 37]. Unfortunately it is often the non-compliant patient or those with no fixed abode that are at greatest risk. Stent encrustation and stone formation is not only one of the most serious complications but its management can also pose the greatest challenge. A further study has stated that stents need not be left in for very long durations for their encrustation burden to become problematic. This retrospective study reviewed 49 encrusted stents which required intervention. Of these 75.5 % were encrusted within 6 months and 42.8 % within 4 months of insertion. All, except one, were successfully treated using a multimodal approach using ESWL, ureteroscopy or PCNL. Only one patient required an open procedure to have the stent removed [38].

Future Developments

Currently biodegradable stents are an attractive option as they are designed to serve a purpose for a short period of time, after which they disintegrate. Hence, there is no need for removal with a second procedure. Another potential benefit of such a stent is decreased bacterial adherence and encrustation as the stent surface is constantly changing as it degrades. This may make the stent softer and more comfortable for patients. Materials currently under development include polyglycolic acid, polylactic acid, poly(lactic-co-glycolic acid) and alginate-based materials [39–41]. The most promising is the Uriprene™ stent and clinical trials are still ongoing [13].

Table 9.3 Complications with ureteric stents [11, 13, 14, 20, 32, 36]

Complication	Summary
Stent symptoms (pain, haematuria, urgency, frequency)	80 % of patients.
Reflux	79 % of stents- causing loin pain.
Stent induced UTI	Bacterial colonisation rates of 40–90 %
	A small subset suffer urinary tract infections.
Stent encrustation	Worse at proximal and distal ends of the stent.
	High risk in patients with urolithiasis or pregnancy
	Dependant on stent duration
	<6 weeks – 9.2 %
	>6 weeks – 47.5 %
	>12 weeks – 76.3 %
Malposition	Incorrect initial placement of ureteric stents
Stent migration	Displacement of the ureteric stent from the correct position
Inadequate relief of obstruction	Incorrect type of stent or the stent is blocked
Stent fracture	Seen with polyethylene stents in the past. These are brittle therefore fractured most commonly at fenestration sites.
Ureteric erosion or fistulisation	Rare complication. Erosion into surrounding structures e.g. vasculature may result in intermittent haematuria.
The forgotten stent	The forgotten stent still occurs despite the advent of stent registries.

Drug eluting stents have an established role in cardiovascular disease. Their use in urology however, has thus far been limited. In 2009, Kotsar et al. described a biodegradable urethral prostatic stent that eluted 5 alpha-reductase inhibitor directly into the prostate of patients with benign prostatic hyperplasia (BPH). The idea was that local inhibition of dihydrotestosterone would help reduce the prostate volume. Unfortunately over half of the patients developed urinary retention in under a month and required supra-pubic catheterisation [42]. Future developments may combine drug eluting prosthetic materials within the urinary tract in order to reduce the incidence of urinary tract infections, target cancer therapy, hormone replacement or deliver chronic pain therapies.

Tissue engineering with the use of autologous chondrocytes seeded onto a tubular biodegradable mesh may also have a role in future stent technology. Along with biodegradability, this stent would be flexible and biocompatible to its host's environment [43, 44].

Conclusion

The ureteric stent is still the most common prosthesis used in urological practice and has evolved significantly since the 1800s. The associated morbidity however, remains a problem. The expanding armamentarium of biomaterials and designs aim to achieve a balance between stent function and comfort. Whilst the perfect stent has yet to be discovered, much hope lies in a future with an ideal biodegradable, tissue engineered, drug-eluting stent.

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