Metal Stents in the Urinary Tract

Evangelos N. Liatsikos,*, Dimitrios Karnabatidis, George C. Kagadis, Paraskevi F. Katsakiori, Jens-Uwe Stolzenburg, George C. Nikiforidis, Petros Perimenis, Dimitrios Siablis

1. Introduction

The successful use of metal stents (MSs) in the vascular and biliary systems led several investigators to propose their use in urology. In 1988, Milroy implanted the first stent in the urinary tract for the treatment of urethral stricture [1]. Over recent years, their use has been expanded in the management of benign conditions, such as benign prostatic hyperplasia, urethral stricture, and detrusor sphincter dyssynergia [2,3]. Urologists initially implanted ureteral stents as a palliative intervention in end-stage malignant disease [4–9]. Treating uretero-intestinal strictures is another application that seems to be challenging. The use of MSs in this situation shows promising results but still has many untoward effects such as tissue ingrowth and recurrent obstruction [10–12].

Urothelial hyperplasia through the stent mesh, encrustation, infection, stent migration, and interaction between stent and ureteral peristalsis are important issues that influence the short-term and especially long-term results after stent insertion in a strictured ureter. Urologists have used various
experimental models to approach these issues and have proposed the use of metal mesh stents coated or covered with biocompatible materials to minimise these side-effects. Still, the ideal MS with radiopacity, low cost, long-term patency as well as resistance to encrustation, infection, and migration is yet to come.

In the present study, we review the current literature and present the latest developments with the application of MSs in the urinary tract.

2. Urethral MSs

2.1. Types and history of urethral stents

The urethra was the first anatomic site of the urinary tract stented by Milroy et al to treat recurrent bulbar urethral stricture after optical urethrotomy [1]. Since then, permanent stents, made from various materials or nondegradable polymers, have been applied in the urethra. Several problems such as encrustation, hyperplasia of the epithelium, and postvoiding dribbling have been reported, leading to the development of temporary urethral stents [13]. The clinical experience with the use of urethral MSs is shown in Table 1.

Three types of MSs have been used to treat recurrent urethral strictures: the self-expanding mesh, the ASI titanium stent, which is a short rigid mesh of titanium wire, and the nitinol stent, which is a flexible spring in one or two parts connected by a steel wire remaining endoluminal [14]. There are some anatomic limitations of the prostatic urethra that may influence the clinical outcome after stent placement. The prostatic urethra does not always conform to the cylindrical shape of the inserted stent. In addition, the bladder neck/urethral angle is not a right angle, thus leading to difficult positioning and probably inadequate epithelial covering of the urethra.

Table 1 – Clinical experience with the use of urethral metal stents

<table>
<thead>
<tr>
<th>Investigators</th>
<th>No. of patients</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Self-reinforced bioabsorbable stents</td>
<td>Laaksovirta et al [41]</td>
<td>39</td>
</tr>
<tr>
<td>Isotalo et al [44,45]</td>
<td>22</td>
<td>Aim: treat recurrent urethral strictures. A self-expandable, self-retaining poly-L-lactic acid double-spiral stent was used in combination with optical urethrotomy in all cases. Free voiding: all patients. Urinary infection: 2 patients. Total epithelialisation of the stent after 6 mo: all patients, except 1. Degradation at 12 mo: all patients. Stricture recurrence: 10 patients. At 46 mo: successful treatment in 8/22 patients.</td>
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<tr>
<td>Covered retrievable expandable nitinol stent</td>
<td>Song et al [25]</td>
<td>12</td>
</tr>
<tr>
<td>Temperature-based memory-shape metal stent</td>
<td>Kamata et al [22]</td>
<td>1</td>
</tr>
<tr>
<td>VanDijk et al [21]</td>
<td>108</td>
<td>Aim: treat severe lower urinary tract symptoms due to benign prostatic enlargement. The bell-shaped nitinol prostatic stent was inserted in all cases. Successful insertion: 97%. Spontaneous voiding: all patients. Main complications: haematuria, urge incontinence, and migration. This stent does not seem suitable for clinical use.</td>
</tr>
<tr>
<td>VanDijk et al [20]</td>
<td>35</td>
<td>Aim: treat lower urinary tract symptoms due to bladder outlet obstruction. An hourglass-shaped nitinol prostatic stent was used in all cases. Failure of insertion: 5 patients. Spontaneous voiding: all patients. Main reason for stent removal: stent migration (93%), in most cases towards the bladder. Uneventful removal: in all, except for 1.</td>
</tr>
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</table>
stent [15]. However, the advantage of stent placement over the conventional urethral catheter, to overcome the urethral stricture, has already been reported with regard to the risk for urinary tract infection [16].

The removal of the urethral stent is still an issue of concern. The permanent stents remain on the urethral wall and keep the lumen permanently open, leading to uncontrolled dribbling after voiding [1]. Besides, they induce mucosal hyperplasia through the stent openings, with the potential risk of stent obstruction. If stent obstruction occurs, repeat endoscopic resection, stent replacement, or even surgical removal may be needed. To resolve these problems, several types of temporarily placed or bioabsorbable urethral stents were introduced [17,18]. Currently, urologists tend to temporarily stent the urethra with the use of bioabsorbable or thermoexpandable memory shape stents. The first ones are biodegraded, leading to self-remotion. The second ones are relatively easily removed due to their nature. They soften at a specific temperature and regain their shape in a different one.

The first bioabsorbable urethral stent was introduced in an experimental animal study by Kempainen et al in 1993 [18]. Bioabsorbable materials used in urology are polyactic acid, polyglycolic acid, and copolymers of lactide and glycoside. The biodegradation time depends on the stent material and processing methods and ranges from 2 to 12 mo. Isotalo et al compared a new braided self-reinforced poly-L-lactic acid (SR-PLLA) urethral stent with the spiral biodegradable SR-PLLA stent and a stainless steel stent in rabbits [19]. The results of this experimental study were encouraging because the degradation of the new stent seemed more controlled and more favourable compared to the disintegration of the previous stent forms. But clinical studies are needed to prove the efficacy of this new stent in the strictured urethra in humans.

Several thermoexpandable shape-memory stents have been used in urethral strictures. Van Dijk et al used a hourglass-shaped nitinol prostatic stent in the management of bladder outlet obstruction. Improvement of the symptoms was observed, but the application of this stent was limited due to high migration rate and, consequently, the need for its removal [20]. The same authors also introduced the use of bell-shaped nitinol stent (Endocare) with promising results [21]. Memokath 028 (Engineers & Doctors A/S, Hombaek, Denmark) was placed by Kamata et al for 6 mo in a 2-yr-old girl with ischiuria after repaired cloacal anomaly. Their observations show that the temporary application of this memory metal stent in paediatric patients with functional obstruction can be a safe and effective alternative [22].

The ideal urethral stent is still under development. Its predominance over the urethral catheter in the treatment of urethral strictures has already been described, but the complications that may occur after stent placement in the urethra minimise its use and prompts a more appropriate urethral stent design.

2.2. The stent influence on the urethra

The interaction between the stent material and the endothelium of the urethra is a significant issue that influences the long-term outcome and the patient’s quality of life after stent placement. Stent obstruction or migration, encrustation, injury of urethra, and formation of granulation tissue are some of these issues. Experimental studies are being conducted to evaluate the possible effects of the stent insertion to the urethra and develop a more appropriate urethral stent (Table 2).

MSs can easily migrate and cause local pain, discomfort, and hyperplasia of the mucosa. Encrustation has been described while using permanent urethral stents [2]. When the MS is fully incorporated into the periurethral tissues, it is difficult to be removed and even surgical procedures may be needed. For this reason, bioabsorbable or temperature-based shape-memory stents are being investigated [18–22]. However, with use of these kinds of stents, migration is more possible. In addition, the sudden breakdown of the bioabsorbable stent may cause urethral obstruction from the broken pieces. Currently, there is a continuous search for the development of bioabsorbable urethral stents with a reduced possibility for migration and urethral obstruction.

Restenosis or blockage of the stent may occur due to either tissue hyperplasia or to formation of granulation tissue. Tissue hyperplasia at either end of a covered stent is usual, leading to difficult stent removal. For this reason, reduction or prevention of the development of tissue hyperplasia is necessary [23]. Granulation tissue formation usually resolves after stent removal [24].

To evaluate the possible interactions between stent and urethral endothelium, Ko et al conducted an experimental study in normal canine urethras [24]. They used a polyurethane-covered retrievable nitinol stent. Migration of the stent (partial or complete) was reported and therefore confined its use. Granulation tissue was observed at both ends of the stent in 17 of 20 dogs. The potential migration and the disruption of the polyurethane membrane
were also some of its limitations. Because of these interactions, the authors concluded that this stent may be suitable for urethral use only after making technical modifications.

Finally, the influence of the stent on the external sphincter when applied to treat nearby strictures is an important issue because it can lead to incontinence after stenting. Song et al proposed the use of a covered, retrievable, expandable nitinol stent to preserve continence after stent placement [25].

### 3. Ureteral MSs

#### 3.1. Types and history of ureteral stents

The aim of ureteral stent implantation is to ensure the unobstructed drainage of urine from the renal pelvis to the bladder. The ideal stent should be inert, resistant to encrustation, and suitable for long-term use; in addition, its implantation in the organ should not cause any pain. The basic characteristics that ureteral stents should have to ensure safe and long-term effective urine drainage are summarised in Table 3.

There are four general types of MSs for ureteral use: the self-expandable, the balloon-expandable, the covered, and the thermoexpandable shape-memory stents. The most commonly used MSs in the ureter are the self-expanding stents, in an effort to minimise tissue ingrowth, which eventually threatens to compromise ureteral patency. The ability of covered stents to reduce tissue ingrowth initially appeared promising but failed to prove efficacy when used in the ureter due to a high rate of migration [26]. The overall experience with the use of ureteral MSs is shown in Table 4.

The Wallstent (Microvasive, Natick, MA) is a self-expandable endoprosthesis and is composed of braided biomedical cobalt-based alloy monofilaments. It is available in a diameter of 7 or 10 mm and in a length of 4, 6, and 8 cm [12].

Memokath 051 (Engineers & Doctors A/S) is a thermoexpandable shape-memory stent, composed of a nickel and titanium alloy [27]. It has a unique

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
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<tr>
<td>Memory</td>
<td>Maintenance of its position within the ureter</td>
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<tr>
<td>Durometer</td>
<td>Strength of memory</td>
</tr>
<tr>
<td>Elasticity</td>
<td>Manipulation of its shape</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>Crystallisation and cross-linking in the biomaterials</td>
</tr>
<tr>
<td>Elongation capacity</td>
<td>Elongation at stent breakage</td>
</tr>
<tr>
<td>Biodurability</td>
<td>Ability to exist within the body without degradation of its structure and function</td>
</tr>
<tr>
<td>Biocompatibility</td>
<td>No significant effect of the stent to the urothelium</td>
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<tr>
<td>Coefficient of friction</td>
<td>Facility of its passage or exchange</td>
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<tr>
<td>Radiopacity</td>
<td>Facility of stent visualisation during fluoroscopy</td>
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</table>
tight spiral structure that prevents endothelial growth. This endoprosthesis softens below 10°C and regains its shape when reheated to 50°C. Because of its thermal shape memory, it is easily removable if indicated. Kulkarni and Bellamy used this MS in managing both benign and malignant ureteral obstruction and showed that this stent has very good long-term results in the management of malignant stricture or recurrent benign strictures. In addition, no stent migration or infection was reported [27,28].

Trueba Arguinarena and Fernandez del Busto used a self-expanding polytetrafluoroethylene-covered nitinol stent (Hemobahn Endoprosthesis, W. L. Gore and Associates, Flagstaff, AZ) to treat both benign and malignant ureteral stenosis [29]. This stent proved to be safe and effective in managing ureteral stenosis and showed high resistance to calcification. Hyperplasia was observed only at the stent ends and only in a few cases and it did not cause obstruction. Migration of the stent occurred in 3 of 20 patients. Long-term follow-up is needed to prove that this covered nitinol stent inhibits ureteral hyperplasia.

Recently, Borin et al published data on a woman with intractable ureteral obstruction due to retroperitoneal fibrosis after metastatic breast cancer. They used a newly developed all-metal double-pigtail Resonance stent (Cook Ireland, Limerick, Ireland), which is constructed of MP35N alloy, a composite of nonmagnetic nickel-cobalt-chromium-molybdenum. The obstruction had previously resisted the insertion of two 6F double-pigtail stents. The ureter was found to be patent in the renal scan at a 4-mo follow-up [30].

<table>
<thead>
<tr>
<th>Type of MS</th>
<th>No. of patients/strictures</th>
<th>Description</th>
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<tbody>
<tr>
<td>Self-expanding and balloon-expandable MS</td>
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<td></td>
</tr>
<tr>
<td>Lugmayr and Pauer [8]</td>
<td>23/30</td>
<td>Follow-up period: 31 wk (3–75 wk), type of obstruction: malignant. Self-expanding MS were used in all strictures. Primary patency was 83% after 30 wk. Macrohaematuria was observed in 1 patient and incrustation in 2 patients.</td>
</tr>
<tr>
<td>Pauer and Lugmayr [9]</td>
<td>12/15</td>
<td>Follow-up period: 3–31 wk, type of obstruction: malignant. Self-expanding MSs were used in all strictures. Haemorrhagia was reported in 1 patient, incrustation in 2 patients, and obstruction distal to the stent in 3 patients.</td>
</tr>
<tr>
<td>Pollak et al [48]</td>
<td>8/11</td>
<td>Type of obstruction: malignant and benign. Two of 5 malignant strictures was occluded within 1 mo and 1/6 benign strictures remained patent in 11 mo.</td>
</tr>
<tr>
<td>Lugmayr and Pauer [5]</td>
<td>40/44</td>
<td>Follow-up period: 10.5 mo (1–44 mo), type of obstruction: malignant. Self-expanding MSs were used in all strictures. 49% needed reintervention and 3 ureters finally had to be abandoned.</td>
</tr>
<tr>
<td>Barbalias et al [4]</td>
<td>12/14</td>
<td>Follow-up period: 9 mo (8–16 mo), type of obstruction: malignant. In 6 patients, we used self-expanding and in the other 6, balloon-expandable MSs. Second intervention was necessary in 3 cases due to urothelial hyperplasia, tumour ingrowth, and local recurrence of primary cancer invading the upper end of the stent.</td>
</tr>
<tr>
<td>Barbalias et al [10]</td>
<td>14/14</td>
<td>Follow-up period: 15 mo (9–24 mo), type of obstruction: malignant. Self-expanding MSs were used in all strictures. Only 2 patients needed further intervention.</td>
</tr>
<tr>
<td>Rapp et al [12]</td>
<td>4/6</td>
<td>Follow-up period: 10 mo (7–12 mo), type of obstruction: malignant. Self-expanding MSs were used in all strictures. No recurrence was observed.</td>
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<tr>
<td>Covered MS</td>
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<tr>
<td>Barbalias et al [26]</td>
<td>16/20</td>
<td>Follow-up period: 8 mos (6–16 mo), type of obstruction: malignant. Thirteen of 16 patients needed second intervention due to stent migration. At the end of the follow-up period, patency was 100%.</td>
</tr>
<tr>
<td>Trueba Arguinarena et al [29]</td>
<td>20/29</td>
<td>Follow-up period: 3 mo for 3 patients, 6 mo for 4 patients, 12 mo for 4 patients, 24 mo for 7 patients; type of obstruction: malignant and benign. In 3 patients, insertion of second stent was needed because of migration of the first stent. At the end of the follow-up period, patency was 100%.</td>
</tr>
<tr>
<td>Thermoexpandable shape-memory MS</td>
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<tr>
<td>Kulkarni and Bellamy [27]</td>
<td>15/22</td>
<td>Follow-up period: 10.6 mo (2–21 mo), type of obstruction: malignant and benign. In 3/15 stent migration occurred and a shorter Memokath 051 (Engineers &amp; Doctors A/S) was inserted because of bladder irritation. At the end of the follow-up period, patency was 100%.</td>
</tr>
<tr>
<td>Kulkarni and Bellamy [28]</td>
<td>28/37</td>
<td>Follow-up period: 19.3 mo (3–35 mo), type of obstruction: malignant and benign. Nine stents in 7 patients were removed, 4 of them requiring no more intervention, 1 led to nephrectomy, 1 to renal failure, and 1 to cystectomy with nephroureterectomy.</td>
</tr>
<tr>
<td>Klarskov et al [49]</td>
<td>33/37</td>
<td>Follow-up period: 14 mo (3–30 mo), type of obstruction: malignant and benign. A total of 22 nonfunctioning stents in approximately 5 mo: 10 of them migrated and 12 malfunctioning. Four stents were occluded by stone after 1–10 mo.</td>
</tr>
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</table>
The insertion technique (antegrade or retrograde) has been previously described in detail [4,31]. Briefly, a standard percutaneous nephrostomy, followed by nephropyeloureterography, is done to exactly define the obstructed segment. The stenosed segment is then passed with the use of a 0.018-, 0.035-, or 0.038-inch guidewire. Dilatation is performed with the use of a high-pressure balloon catheter (8–10 mm diameter; Fig. 1). The space for stent passage is then adequate and the endoprosthesis is inserted over the guidewire. It is placed in such a position that the upper end bypasses the stricture by at least 3–4 cm while the lower end extends intravesically for 0.5–1 cm from the ureteral orifice. Two or more MSs can be placed in sequence if necessary, overlapping by at least 2–3 cm to bridge longer obstructed ureteral segments. If the MS does not expand to the desired diameter, supplementary balloon dilatations may be performed.

After the stent placement is completed, a plain radiograph of kidneys-ureters-bladder, ultrasonography, and antegrade nephrotomography are obtained to confirm ureteral patency. The nephrostomy tube can then be removed. Urinalysis, urine culture, serum creatinine measurement, transabdominal ultrasonography, and excretory urography are performed in scheduled order (Fig. 2). Renography with diethylenetriamine pentaacetic acid (DTPA) can be performed if indicated and ureteroscopy may be necessary to assess and treat eventual encrustations. Virtual endoscopy (VE) has also been proposed as a noninvasive method to evaluate patency of the stented ureter [32–34] (Fig. 3).

Since the first stent implantation in the ureter, considerable efforts have been made to improve stent design, aiming to facilitate insertion, prevent migration, and permit maximum flow of urine into the bladder. Nevertheless, the ideal stent does not exist.

### 3.2. The stent influence on the ureter

Urothelial hyperplasia of the stent lumen has been the principal problem after the insertion of a metal prosthesis in the ureter (Fig. 4). It is a common phenomenon that may influence patency of the stented ureter and has been verified endoscopically. Thijssen et al have shown that the grade of urothelial hyperplasia seems to depend on the degree of the force exerted on the ureteral wall as well as on the extent of the ureteral overstretching and the resulting urothelial trauma [35]. Desgrandchamps et al conducted an experimental study in pigs, inserting eight stents. Only one of them was observed to be patent 35 d after the insertion [36]. Careful insertion of the stent with avoidance of overextending the strictured area of the ureter is needed. Urothelial hyperplasia usually regresses 4–6 wk after the insertion of the stent, avoiding the narrowing of the ureteral lumen [4,5,8–10]. Flueckiger et al reported that during the first 2 wk after the stent insertion reactive swelling of the urothelium, but not hyperplasia, occurs, leading to constriction of the ureteral lumen [7].
The concept of a covered MS was introduced to overcome the problem of hyperplasia growth. Nevertheless, migration of a coated MS may occur, with a frequency of 81.2% observed in one of our previous publications [26]. Migration may be corrected by coaxial insertion of another prosthesis. In a previous study, we implanted coated MSs in 16 patients with malignant ureteral stricture. Thirteen of the 16 showed migration of the endoprosthesis, which caused ureteral obstruction and subsequently ipsilateral lumbar pain. The floating stents were removed cystoscopically from the bladder and bare MSs were then implanted, achieving ureteral patency for a mean follow-up of 8 mo [26]. The high and fast migration rate of the coated stents into the bladder, the confirmed “non-anchor-age” of the coated stents into the ureteral wall due to the presence of the coating material, and, finally, the enhanced ureteral peristalsis are considered strong arguments against the use of coated stents for the management of ureteral strictures.

In our previous publications, we described a trumpet-like configuration of the ureter adjacent to the upper extremity of the MS, which did not hinder ureteral patency [10,26] (Fig. 5). The autopsy findings in a patient with malignant ureteral stricture, who died 2 mo after MS implantation, revealed a fibrotic reaction in the lumen of the balloon expandable

Fig. 3 – Virtual endoscopy. (a) Patent stented ureteral lumen and (b) stenotic distal part of the endoprosthesis.

Fig. 4 – Excretory urography: urothelial hyperplasia jeopardising luminal patency.

Fig. 5 – Computed tomography/three-dimensional reconstruction: trumpet-like configuration adjacent to the proximal end of the metal stent.
stent, probably due to an overextension of the ureteral wall causing urothelial trauma [4].

The effect of the MS on ureteral dynamics is an issue of controversy. The presence of foreign material in a peristaltic organ increases the peristalsis of the organ aiming to ascertain lumen patency. Hemikoglu et al suggested that the aperistaltic segment of the stented ureter in conjunction with urothelial peristalsis causes urinary stasis and thus encrustation of the uncovered areas of the MS [37].

Encrustation of the MS is a significant factor that may limit the long-term use of the ureteral endoprosthesis. Both the biomaterial and the patient’s history influence the risk of encrustation. Tunney et al compared the resistance of different stent biomaterials to encrustation and concluded that a stent resistant to encrustation should be formed from a biomaterial resistant to bacterial infection and subsequent biofilm formation [38]. Pauer and Lugmayr reported the presence of encrustations in a small area of Wallstents that was not covered by endothelium because it did not embrace the ureteral wall [9].

Experimental studies are being conducted to investigate the microscopic urothelial changes that occur after stent implantation as well as to develop a covered or coated endoprosthesis that will minimise complications (Table 5). Greater understanding of the interaction between the stent material and urine, with improvements in biomedical engineering, may reduce some of the undesirable events associated with ureteral stenting.

4. Our experience

Our experience with MSs dates back to 1997 when we applied self- and balloon-expandable MSs in the management of malignant disease in 12 patients. A secondary intervention was necessary in three of them due to urothelial hyperplasia, tumour ingrowth, or recurrence of primary tumour in the upper end of stent [4]. Consequently, we applied MSs in the treatment of benign anastomotic strictures developed after ureteroileal diversion and afterwards in ureteropelvic junction obstruction with encouraging results [10,33].

MSs covered with various biocompatible materials have already been used with success in the vascular arena and with better clinical outcome compared to bare MSs. The aim was to limit the ingrowth of intimal hyperplasia along the length of the treated arterial segment and thereby to improve patency as compared to conventional angioplasty and stenting. This observation in the vascular system has led urologists to experimentally use this kind of stent in the urinary tract. Their main

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Issue</th>
<th>Description</th>
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<tbody>
<tr>
<td>Wrigth et al [50]</td>
<td>Placement of self- and balloon-expandable metal stents (MSs) in normal/stenotic canine ureters</td>
<td>Complete occlusion in all stented ureters due to mucosal hyperplasia in 4–8 wk. Distal narrowing was observed, due to functional discrepancy between adynamic stented ureter and normal underlying ureter. Urothelial hyperplasia was another feature, but it did not play an important role in obstructing porcine ureters.</td>
</tr>
<tr>
<td>Desgrandchamps et al [36]</td>
<td>Placement of self-expanding MS in pig ureters</td>
<td></td>
</tr>
<tr>
<td>Liatsikos et al [39]</td>
<td>Placement of bare MS and internally or externally coated MS in normal pig ureters</td>
<td>Coated stents cause minimal tissue ingrowth but tend to migrate towards bladder, whereas bare MSs cause less inflammation of surrounding tissues.</td>
</tr>
<tr>
<td>Thijssen et al [35]</td>
<td>Placement of self-expanding MS in histologically normal canine ureters</td>
<td>Ureters remained patent. MS was not incorporated within the ureter wall. Penetration of epithelium/submucosa between wire struts and areas of fibrosis in submucosal layer were observed.</td>
</tr>
<tr>
<td>Antimisiaris et al [51]</td>
<td>Simulation of in vivo conditions after the placement of a liposome-covered MS, which slowly releases dexamethasone</td>
<td>May be an efficient method of treating ureteral stent obstruction.</td>
</tr>
<tr>
<td>Leveillee et al [52]</td>
<td>Bare MS and MS lined with porous biocompatible polymer in canine ureters</td>
<td>MSs lined with a biocompatible material help prevent tissue ingrowth, whereas bare MSs cause ureteral obstruction and hydronephrosis. Paclitaxel-DES generated less inflammation and less hyperplasia of surrounding tissues, thus maintaining ureteral patency.</td>
</tr>
<tr>
<td>Liatsikos et al [40]</td>
<td>Placement of bare MS and paclitaxel drug-eluting stent (DES) in normal pig ureters</td>
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disadvantage is the high rate of migration, the intense inflammatory reaction of the urothelium due to the presence of the lining material, and, finally, the easier infection of this kind of stent compared to the indigenous grafts. The more intensive inflammatory reaction generates fibrous tissue that is compressed beneath the prosthesis. Still, clinical experience is limited and further experimental as well as clinical investigation is deemed necessary for their evaluation in the urinary tract.

To find a more appropriate MS and improve our results, we conducted an experimental study in pigs, using internally and externally coated MSs, and compared the results between coated and bare MSs. The follow-up led to controversial outcomes. The bare MSs generated less inflammation of the surrounding tissues but coated stents had the advantage of minimal tissue ingrowth. Additionally, coated stents tended to migrate into the bladder, jeopardising ureteral patency [39]. Consequently, we placed covered MSs in 16 patients with malignant ureteral obstruction but unfavourable clinical results were observed. No local or systemic infection was described, but a high and fast migration rate of the MS into the bladder occurred due to “non-anchorage” of the implanted stent into the ureteral wall. This finding was considered to be a strong argument against their use in the ureter [26].

Recently, we published our experience with the use of a drug-eluting stent (DES) in an experimental pig model. The results seem promising. DESs are used in the treatment of strictures of coronary vessels, aiming to minimise the risk of restenosis. It has been shown that they reduce inflammation and smooth muscle proliferation. We thus postulated that they may have similar tissue effects in the urinary tract and reduce potential luminal occlusion in the stented ureter. Less inflammation and less hyperplasia of surrounding tissues were observed with DESs compared to bare MSs, thereby maintaining ureteral patency (Fig. 6). Still, long-term animal and human trials are needed to further validate these promising initial results [40].

5. New perspectives

Since the first stent implantation in the field of urology, efforts have been made to improve stent design but still the ideal MS has not been developed. The use of coated or covered MSs as well as bioabsorbable stents seems promising in minimising stent-related morbidity and improving long-term urine drainage into the bladder [23,40–43]. Pharmacologically active agents can be incorporated onto covered or coated MSs. The agent may be placed either directly to the polymeric surface of the stent (coated MS) or into the core of the stent’s polymeric structure (DES). In the first case, the agent is pharmacologically active at the surface and can prevent infection or encrustation, whereas in the second case, the pharmacologic agent is delivered locally in a sustained-release fashion and may have potential activity at the urothelium.

Experimental studies with the application of DESs have already been initiated in both the urethra and the ureter. DESs tend to reduce neointimal hyperplasia by inhibiting vascular smooth muscle cell proliferation and migration. We used a paclitaxel-eluting covered stent in the pig ureter model with promising results [40]. Shin et al applied a similar stent in a canine urethral model and described less tissue hyperplasia reaction compared to polyurethane-covered stents [23]. DESs are being used in the treatment of strictures in coronary vessels to
minimise the risk of restenosis because they reduce inflammation and smooth muscle proliferation. We tend to believe that the application of DESs will solve many of the problems of stenting in the urinary tract, but more long-term animal and human trials are needed to prove their efficacy in this field. However, a retrievable stent design is needed in DESs to make the removal easier [23].

Bioabsorbable stents are still being developed. Little is known about their behaviour in the urinary tract but the first results seem promising. Isotalo et al evaluated the use of a bioabsorbable SR-PLLCA urethral stent combined with optical urethrotomy in the treatment of recurrent urethral stricture in 22 patients [44]. Thirteen recurrent strictures were reported within 15 mo. At 6 mo, the stent was totally epithelialised in almost all patients and at 12 mo, the stents were totally degraded in all patients. Their long-term results showed that in most of the patients with stricture recurrence at the stent site, the recurrence was discovered during the weakening of the stent [45]. The stent seems to collapse, leading to permanent urethral obstruction, if sudden heavy compression happens during the early degradation period. The biocompatibility of the bioabsorbable stents has been reported to be good [17,18,46].

6. Conclusions

The application of MSs in the urinary tract has improved clinical outcome in the treatment of urinary tract strictures and is currently thought to be a useful tool in urology practice. Considerable efforts are being made to optimise stent biomaterial, the coating, and, in general, the ureteral stent design. Continuing the research interest seems to be essential for further clinical improvement, aiming to minimise stent-related morbidity.

References

Credits will then be attributed automatically.


1. The clinical outcome after insertion of a urethral MS may be influenced by:
   A. Anatomic limitation of the prostatic urethra
   B. Stent material
   C. Insertion technique
   D. None of the above

CME questions

Please visit www.eu-acme.org/europeanurology to answer these CME questions on-line. The CME credits will then be attributed automatically.
2. The biodegradation time of the biodegradable materials used in urology is:
   A. 1 mo
   B. 13–18 mo
   C. 2–12 mo
   D. None of the above

3. The main limitation of ureteral MS insertion is:
   A. Migration
   B. Urothelial hyperplasia
   C. Encrustation
   D. None of the above

4. Covered MSs were used:
   A. To overcome the problem of hyperplastic reaction
   B. For better anchorage
   C. To reduce encrustation
   D. None of the above

5. Drug-eluting MSs have been shown to:
   A. Be toxic on the tissue
   B. Reduce migration
   C. Reduce inflammation and hyperplastic reaction
   D. Increase inflammation and hyperplastic reaction

6. Insertion of a ureteral MS:
   A. Can be performed in an antegrade fashion
   B. Can be performed in a retrograde fashion
   C. Combination of A and B
   D. Can be performed with ureteroscopic guidance