


HANDBOOK OF URINARY STENTS

BASIC SCIENCE AND CLINICAL APPLICATIONS

Noor Buchholz
Oliver Hakenberg
Junaid Masood
Christian Bach

JP

17/02/2015 12:34

Contents

Preface		v
Contributors		xi
SECTION 1	**URETER STENTS**	**1**
Chapter 1	**History of ureteric stents** Daniel Yachia	**3**
Chapter 2	**Physiology of stent flow** Tamer El-Husseiny, Martin Knight	**7**
Chapter 3	**Stent materials and designs** Dirk Lange, Claudia Janssen, Ben H. Chew	**15**
Chapter 4	**Urinary stent coatings** Patrick Zammit	**21**
SECTION 2	**POLYMER STENTS**	**33**
Chapter 5	**Ureter stents: indications** M. Hammad Ather	**35**
Chapter 6	**Polymer stents: insertion tips and tricks** Anuj Goyal, Athanasios Papatsoris, Junaid Masood	**41**
Chapter 7	**Complications of ureteric stents and how to deal with them** Jens Mundhenk, Noor Buchholz	**49**
Chapter 8	**How to deal with heavily encrusted stents** Bannakij Lojanapiwat	**55**
Chapter 9	**Medical management of ureteral stent-related symptoms** Giovanni S. Marchini, Manoj Monga	**61**

Chapter 10	**Stents in children** Kemal Sarica, Oktay Akca	71
Chapter 11	**How not to forget the stent** Kyle David Wood, Jorge Gutierrez	75
Chapter 12	**Indwelling ureteric stents: the patient's stent experience and health-related quality of life** Hrishi B. Joshi	81
SECTION 3:	**METAL STENTS**	89
Chapter 13	**The role of metal in stents** Mette Holm	91
Chapter 14	**The Memokath stent** Stefanos Kachrilas, Ali Panah, Rebecca Dale, Andreas Bourdoumis, Faruquz Zaman, Athanasios Papatsoris, Noor Buchholz, Junaid Masood	97
Chapter 15	**The Resonance stent** Panagiotis Kallidonis, Iason Kyriazis, Ioannis Georgiopoulos, Evangelos N. Liatsikos	117
Chapter 16	**The ureteral metal mesh stent** Panagiotis Kallidonis, Ioannis Georgiopoulos, Iason Kyriazis, Evangelos N. Liatsikos	123
Chapter 17	**The Allium stent** Carlo De Dominicis, Francesco De Luca, Costantino Leonardo	129
Chapter 18	**The Uventa stent** Seol Ho Choo, Kyung Jin Chung, Deok Hyun Han, Shin Woo Lee	135
Chapter 19	**Complications of metal stents in the ureter** Palle Jörn Sloth Osther	141

Chapter 20	**Pathophysiology of encrustation in metal stents** Anuj Goyal, Martin Knight	**151**
Chapter 21	**Prophylactic shock wave lithotripsy for metal stents** Christian Bach	**159**
Chapter 22	**Quality of life with metal stents** Azad Hawizy	**163**
Chapter 23	**Use of metal stents in transplant ureteral stricture** Mohammad F. Zaman, Islam Junaid	**169**
Chapter 24	**Using the Wallstent in the management of benign ureteroenteric anastomotic strictures in Bricker deviation** Tycho M. T. W. Lock, Thijs Campschroer, Rob H. Lo	**177**
Chapter 25	**Biodegradable materials in ureter stents** Martti Talja, Juha Lumiaho	**187**
Chapter 26	**Drug-eluting ureter stents** Wolfgang Kram, Oliver W. Hakenberg	**193**
SECTION 4	**LOWER URINARY TRACT STENTS**	**205**
Chapter 27	**History of lower urinary tract stenting** Daniel Yachia	**207**
Chapter 28	**Lower urinary tract stents: the ideal stent** Roy Morag, Mordechai Duvdevani	**213**
Chapter 29	**Physiology of urethral flow** Andreas Bourdoumis, Noor Buchholz, Martin Knight	**219**

SECTION 5	**PROSTATE STENTS**	**227**
Chapter 30	**Prostate stents: indications** Datesh Daneshwar, Christian Bach	**229**
Chapter 31	**Temporary intraprostatic stents** Michael Samarinas, Stavros Gravas, Jean J. M. C. H. de la Rosette	**233**
Chapter 32	**The Memokath prostate stent** Athanasios Papatsoris, Andreas Skolarikos, Athanasios Dellis, Noor Buchholz, Junaid Masood	**241**
Chapter 33	**The UroLume prostate stent** Nadir I. Osman, Christopher R. Chapple	**247**
Chapter 34	**The Allium prostate stent** Zeljko Markovic, Ana Mladenovic	**253**
Chapter 35	**The Spanner prostate stent** Matthew Goh, Anthony Timoney	**261**
Chapter 36	**Complications of prostate stents** Julian Shah	**267**
Chapter 37	**The future role of prostatic stents** Andreas Bourdoumis, Stefanos Kachrilas, Azad Hawizy, Noor Buchholz, Junaid Masood	**273**
SECTION 6	**URETHRAL STENTS**	**287**
Chapter 38	**Urethral stents: indications** Panos Christopoulos, Andreas Bourdoumis, Stefanos Kachrilas, Noor Buchholz, Junaid Masood	**289**
Chapter 39	**The Allium urethral stent** Stéphane Droupy	**293**

Chapter 40	**The urethral stent and detrusor–sphincter dyssynergia** André van der Merwe	299
Chapter 41	**The urethral stent and radiotherapy** Jesper Carl	305
Chapter 42	**Brachytherapy and the urethral stent** Athanasios Dellis, Junaid Masood, Noor Buchholz, Athanasios Papatsoris	311
Chapter 43	**The future role of urethral stents** Rizwan Hamid	317
Chapter 44	**Biodegradable stents of the lower urinary tract** Andres Kotsar, Martti Talja	321
Chapter 45	**The future of ureteral stents** Andreas Bourdoumis, Noor Bucholz, Athanasios Papatsoris	329
Index		339

2 Physiology of stent flow

- Mechanisms of flow through conventional JJ stents: page 7
- Obstructed stents: page 8
- Other types of ureteral stents: page 10
- Reflux: page 12
- Conclusion: page 12

Historically, treatment of ureteric obstruction often necessitated urinary diversion via a percutaneous nephrostomy tube, but with the advent of minimally invasive urological techniques the use of ureteral stents has gained more popularity owing to the practicality and wider acceptance of the stents by patients. It has been well documented that stent placement relieves almost all obstruction due to intrinsic pathology (e.g. stones). Ureteric stents now have a widespread range of applications in day-to-day urological practice. They are used to treat benign and malignant ureteric strictures, to facilitate upper tract urinary drainage following ureteroscopic stone surgery or extracorporeal shockwave lithotripsy, or to splint the ureter following ureteric trauma. Fundamental to these applications is the maintenance of adequate drainage from the kidney during the stenting period.

In a healthy body, the urinary tract acts as a conduit and reservoir for urine that is produced and excreted by the kidney. After production, urine collects in the renal pelvis of the kidney and passes down the ureter to the bladder, where it is stored at low pressure until micturition occurs.

Normal ureteral flow mechanics are a combination of differential pressures between the kidney and bladder and the ureteral wall peristalsis,[1] which pushes urine down the ureter to the bladder at flow rates of 0.5–10 mL/min for each kidney/ureter.

This chapter addresses the nature of urine flow in the stented ureter, which has important implications for optimal stent design and usage.

Mechanisms of flow through conventional JJ stents

Ureteral JJ stents are commonly a flexible, cylindrical length of synthetic polymeric composite with a central lumen down its axis. The lumen of the stent provides a direct path for urine to flow through (intraluminal flow) in addition to any space existing between the outer stent surface and ureteral mucosa (extraluminal flow). To improve functionality, the stent has a series of holes perpendicular to the long axis that enable interchange between intraluminal and extraluminal flow thereby helping to bypass any future obstructions that may develop.[2]

Various studies have looked into the mechanism of flow in stented ureters and whether this is mainly attributed to intraluminal or extraluminal flow. Brewer et al.[3] described a porcine model for

JAYPEE BROTHERS

assessing the in vivo flow characteristics of stents of varying sizes and configurations. They determined that luminal and extraluminal flow components contribute to overall stent drainage, with the luminal and total flow appearing to be most directly affected by stent internal diameter. This is supported by an in vitro study using a simulated urinary system. In this study, Mardis et al.[4] determined that greater flow rates occurred using stents with larger internal diameters and with side holes along the shaft. Similarly, Hafron et al.[5] in an ex vivo study reported that increased luminal diameter was directly related to the increased flow. This is reflected by fundamental fluid dynamics and Poiseuille's law, which states that for a given driving pressure the fluid flow rate is proportional to the diameter of the conduit and inversely proportional to its length. Thus, larger diameter stents would have least resistance to flow, which would be predominantly intraluminal. However, this physical relationship only applies when the stent lumen is entirely filled with fluid and is the sole flow pathway. Both may not occur in vivo. Indeed, Ramsay et al.[6] reported that in a stented ureter, urine flow is preferentially extraluminal due to dilatation of the ureteral lumen in response to the indwelling prosthesis. Thus, they also reported similar flow rates for two different sized ureteral stents.

Alternatively, Hubner et al.[7] showed that it was the stiffness of the stent material that significantly changed the pressure flow characteristics and that the luminal diameter is not an important factor in the physiologic urine flow rates. They concluded that smaller stents adequately drain the renal pelvis under normal physiological conditions providing the stiffness of the stent material was sufficient to maintain flow in cases of extrinsic ureteral compression.

Tong et al.[8] have used numerical simulation to assess the flow of fluid in and around stents with side holes. They found that in the absence of obstruction most side holes are inactive except the holes immediately adjacent to the coil at each end, while in presence of obstruction to the stent lumen, flow occurs through multiple holes.

Obstructed stents

The typical JJ ureteral stent allows efficient urine flow through and around the stent. However, ureteric stents may become obstructed due to debris, mucus, and residual stones[1] Intraluminal stent obstruction may also arise due to encrustation (**Figures 2.1** and **2.2**) and other debris that may be produced in direct response to the presence of the stent. Restricting side holes to the pigtail portion of the stent has been proposed as a means to decrease this adverse outcome[9] Periureteral stent flow is also compromised when an external mass compresses, kinks, and obliterates the space around a stent.[6] For example, Docimo and Dewolf[9] reported a >45% chance of stent occlusion with extrinsic compression. This combination leads to the simultaneous obstruction of the intraluminal and extraluminal stent flow, resulting

JAYPEE BROTHERS



Figure 2.1 In vitro encrustation model of double-J stent.



Figure 2.2 In vitro encrustation model of Memokath stent.

in stent failure.[10] The rationale behind this difficulty in bypassing an obstruction due to an extrinsic pathology is only partially understood and this, in addition to the nature of the disease process in cases of extrinsic ureteric compression, represents a real management dilemma to most urologists. Efforts to optimize the success rate of ureteral stents for malignant compression have produced varied results. Fromer et al.[11] have described the placement of two parallel ureteral stents. The theoretic advantage of parallel stents is that extraluminal flow is maintained in the potential space between them. The need for temporary removable stents with improved resistance to extrinsic compression, encrustation, and blockage has led to the development of a variety of alternative stent designs.

JAYPEE BROTHERS

Other types of ureteral stent

Recently and with the technologic advancements in industry, there have been some studies describing the pattern of urine flow across novel ureteral stents and evaluating their role in management of malignant ureteral obstruction. Blaschko et al.[12] studied the in vivo flow characteristics of the Resonance metallic ureteral stent (a novel, nickel–cobalt–chromium–molybdenum alloy stent, Cook Medical, IN, USA) (**Figure 2.3**), which is a 6-Fr stent with flexible, tightly coiled, double-pigtail wire design with a patent lumen and occluded ends. They have shown that in a non-compressed ureter the conventional 6 Fr JJ stent had greater intraluminal flow rates than the Resonance stent. However, the non-compressible nature of the Resonance stent significantly improves drainage in the ureter when an external compressive force is applied to the stent surface. This is possibly due to increased flow between the coils of the metal stent after compression, which clinically simulates the clinical situation of extrinsic ureteral compression from malignancy in which extraluminal flow is compromised.

Christman et al.[13] conducted in vitro mechanical testing on different types of ureteral stents looking at the compression forces required to compress the stent to 50% of its original external diameter. They found that the Silhouette 4.6 Fr, 6 Fr, and 8 Fr ureteral stents (Applied Medical, CA, USA), and the Resonance 6 Fr stent had significantly greater resistance to compression than all of the other stents tested. This increased resistance to compression was uniform along the length of the stent and without any sacrifice in inner luminal diameter.

The Memokath 051 (**Figure 2.4**) is a newly developed thermo-expandable, nickel–titanium alloy stent (PNN Medical A/S, Kvistgaard, Denmark). The current Memokath 051 is 10.5 Fr in shaft diameter and has a fluted end that expands to 22 Fr. Different lengths are on the market at 30, 60, 100, 150, and 200 mm depending on stricture length.

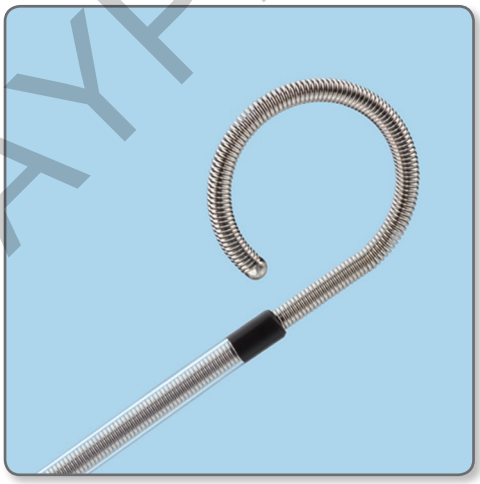

Figure 2.3 The Resonance stent. By courtesy of Cook Medical, Bloomington, Indiana, USA.

JAYPEE BROTHERS

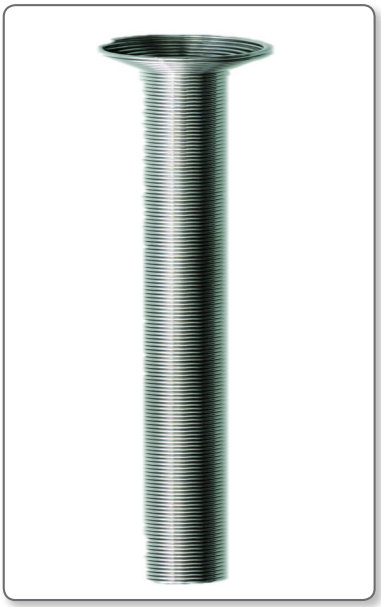

Figure 2.4 The Memokath 051 stent. By courtesy of PNN Medical Kvistgaard, Denmark.

Although no published studies to date have looked into the mechanism of urine flow in this relatively new stent, the much wider stent lumen suggests that the flow dynamics are mainly intraluminal.[14,15] This may also contribute to the lower reported encrustation rates compared to the conventional JJ stents.

Another newly developed stent, the Allium URS (Allium Medical Solutions LTD, Israel), is a self-expanding, large caliber metal stent especially designed for the ureter. The metal self-expanding component of the stent is made of a superelastic nickel–titanium alloy (nitinol). The entire stent is covered with a new biocompatible, biostable polymer to make it a non-permeable tube to prevent tissue ingrowth into the lumen and early encrustation (**Figure 2.5**). The Allium URS comes in two calibers (24 Fr and 30 Fr) and in two lengths (10 cm and 12 cm). It has a main body with high radial force with softer end segments. Longitudinally the URS is very flexible and has a strong enough radial



Figure 2.5 The Allium URS stent. By courtesy of Allium Medical, Israel.

JAYPEE BROTHERS

force to ensure lumen patency by providing direct ureteric wall support, thus allowing maximal intraluminal flow.[16]

Reflux

During normal function, when the intravesical pressure rises (as in situations of full bladder or during voiding) the vesicoureteric junction (VUJ) contracts and closes as the rising pressure compresses the intramural portion of the ureter, thus preventing vesicoureteric reflux (VUR) in what is known as the natural antireflux mechanism. However, after stenting, the VUJ is held open by the stent and the natural antireflux mechanism becomes compromised which results in VUR. Certainly, this does not apply to segmental ureteric stents when they are used more proximally in the ureter where a functional VUJ antireflux mechanism is preserved. Mosli et al.[17] reported that reflux in stented ureters occurred in 19 of the 30 renal units (63%) during the filling phase of the cystourethogram and in 24 of the 30 renal units (80%) during the voiding phase of the cystourethogram. These findings were also supported by Shao et al.[18] who recently studied the in vivo influence of ureteral stents on renal pelvic pressures and found that renal pelvic pressure increased mildly during the filling phase and dramatically during the voiding phase after stenting.

In an attempt to minimize this, a new JJ stent with antireflux mechanism has been developed. Although not widely used yet in clinical practice, several studies have shown promising results for this type of stents in reducing the rate of VUR and the overall rate of stent related morbidity.[19-21]

Conclusion

Ureteral stents have widespread application in present day urological practice. Stent flow studies have shown variable results, some attributing it mainly to intraluminal flow whereas others to extraluminal flow, suggesting that the flow pathway may depend on the stent design, and to a patient's anatomy and response to the implant.

A better understanding of the complex flow involved in urine transport through a stented ureter would provide insight for improved designs to enhance patient health and comfort, and will also allow the treating urologists to choose the most suitable stent. Further research is required in this field especially to study the flow characteristics and reflux in newly marketed stents and the influence of obstruction and encrustation.

JAYPEE BROTHERS

References

1. Stoller ML, Schwartz BF, Frigstad JR, et al. An in vitro assessment of the flow characteristics of spiral-ridged and smooth-walled JJ ureteric stents. Br J Urol Int 2000; 85:628–631.
2. Bevan T, Carriveau R, Goneau L, et al. Numerical simulation of peristaltic urine flow in a stented ureter. Am J Biomed Sci 2012; 4:223.
3. Brewer AV, Elbahnasy AM, Bercowsky E, et al. Mechanism of ureteral stent flow: A comparative in vivo study. J Endourol 1999; 13:269–271.
4. Mardis HK, Kroeger RM, Hepperlen TW, Mazer MJ, Kammandel H. Polyethylene double-pigtail ureteral stents. Urol Clin North Am 1982; 9:95–101.
5. Hafron J, Ost MC, Tan BJ, et al. Novel dual-lumen ureteral stents provide better ureteral flow than single ureteral stent in ex vivo porcine kidney model of extrinsic ureteral obstruction. Urology 2006; 68:911–915.
6. Ramsay JWA, Payne SR, Gosling PT, et al. The effects of double-J stenting on unobstructed ureters: an experimental and clinical study. Br J Urol 1985; 57:630.
7. Hubner WA, Plas EG, Stoller ML. The double-J ureteral stent: in vivo flow studies. J Urol 1992; 148:278–280.
8. Tong JC, Sparrow EM, Abraham JP. Numerical simulation of urine flow in a stented ureter. J Biomech Eng 2007; 129:187–192.
9. Docimo SG, Dewolf WC. High failure rate of indwelling ureteral stents in patients with extrinsic obstruction: experience at 2 institutions. J Urol 1989; 142:277.
10. Chung SY, Stein RJ, Landsittel D, et al. 15-year experience with the management of extrinsic ureteral obstruction with indwelling ureteral stents. J Urol 2004; 172:592–595.
11. Fromer DL, Shabsigh A, Benson MC, Gupta M. Simultaneous multiple double pigtail stents for malignant ureteral obstruction. Urology 2002; 59:594–596.
12. Blaschko S, Deane LA, Krebs A, et al. In-vivo evaluation of flow characteristics of novel metal ureteral stent. J Endourol 2007; 21:780–783.
13. Christman MS, L'esperance JO, Choe CH, Stroup SP, Auge BK. Analysis of ureteral stent compression force and its role in malignant obstruction. J Urol 2009; 181:392–396.
14. Staios D, Shergill I, Thwaini A, Junaid I, Buchholz NP. The Memokath stent. Expert Rev Med Devices 2007; 4:99–101.
15. Papatsoris AG, Masood J, El-Husseiny T, et al. A novel long-term thermo-expandable ureteric metal stent: Memokath 051TM. BJU International website. Fitzpatrick JM, Drake M, Webber R (eds.), Atlas of surgical devices, 2008.
16. Moskovitz B, Halachmi S, Nativ O. A new self-expanding, large-caliber ureteral stent: results of a multicenter experience. J Endourol 2012; 26:1523–1527.
17. Mosli HA, Farsi HM, Al-zimaity MF, Saleh TR, al-Zamzami MM. Vesicoureteral reflux in patients with double pigtail stent. J Urol 1991; 146:966–969.
18. Shao Y, Shen Z, Zhuo J, et al. The influence of ureteral stent on renal pelvic pressure in vivo. Urol Res 2009; 37:221–225.
19. Ritter M, Krombach P, Knoll T, Michel MS, Haecker A. Initial experience with a newly developed antirefluxive ureter stent. Urol Res 2012; 40:349–353.
20. Ecke TH, Bartel P, Hallmann S, et al. Evaluation of symptoms and patients' comfort for JJ-ureteral stents with and without antireflux-membrane valve. Urology 2010; 75:212–216.
21. Hübner WA, Plas EG, Trigo-Rocha F, Tanagho EA.. Drainage and reflux characteristics of antireflux ureteral double-J stents. J Endourol 1993; 7:497–499.

JAYPEE BROTHERS

HANDBOOK OF URINARY STENTS

BASIC SCIENCE AND CLINICAL APPLICATIONS

Urologists have long used ureteric stents in the treatment of patients who have, or who are at risk of developing, an obstruction in the flow of urine from the kidneys. These tube-like devices are inserted into the ureter to maintain an open canal or to help with healing after trauma, surgery or radiotherapy.

Recent developments have led to the introduction of a new generation of stents for use not just in the ureter but also in the prostate and urethra. These employ a variety of designs, materials and coatings and aim to counter side effects such as dislocation, irritation, infection and encrustation.

Handbook of Urinary Stents: Basic Science and Clinical Applications has been written to provide urologists with a practical guide to the various stents available to clinicians today, the criteria for their selection, their clinical application and potential complications of use.

- Provides a comprehensive overview for urologists needing an accessible guide to the range of stents available
- Emphasizes clinical complications in the use of stents and how to manage them effectively
- Describes the use of stents in all the organs of the urinary system and in all materials – metal, polymeric and biodegradable

JP medical publishers

www.jpmedpub.com

ISBN 978-1-907816-65-9

Buchholz_240x160mm_AW.indd 1