

Techniques of Robotic Urinary Tract Reconstruction

A Complete Approach

Michael D. Stifelman

Lee C. Zhao

Daniel D. Eun

Chester J. Koh

Editors

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Part I

Prologue:

If you have picked up this book, you too have had your robotic “aha” moment. Mine happened in 2003, when introduced to a three-arm, first generation intuitive system while struggling to learn laparoscopic suturing as a junior attending. It was clear this would become the great equalizer; one could maintain a steady camera with complete autonomy. Beyond that, the 3D imaging and endowrist technology made delicate dissection and complex suturing within grasp, coupled with a much shorter learning curve. Since the introduction of robotic surgery almost 2 decades ago, there have been innovators, early adopters, and pioneers all focused on robotic upper urinary tract reconstruction. Those that focused on urinary reconstruction surgery had diverse backgrounds including endourology, urologic oncology and urinary reconstruction. This varied and eclectic group of urologic surgeons provided a melting pot of ideas, and their willingness to share their techniques, successes, and failures allowed us to literally “build the plane as we were flying it.” The progress made since the first publication on a robotic urinary tract reconstruction case has been remarkable. Leveraging the latest in robotic technology, incorporating perfusion imaging intraoperatively, and challenging the paradigm of managing proximal and mid ureteral strictures are just some of the accomplishments that have changed our patients’ outcomes for the better. It has been the work of many and the relationships made while “building the plane” that allowed us to realize this book. The major catalyst, and the event that set the wheels in motion came in May 2018, while the 4 editors were sharing a beer, in San Francisco, after completing our third annual AUA course entitled “Robotic Urinary Tract Reconstruction: A Top to Bottom Approach.” Despite three hours of content, it was just the tip of the iceberg. We all felt as if there was so much more to say and so many people to connect with that we were only scratching the surface. In addition, we wanted to spare the next generation of urologists from having to build their own plane from scratch. As we gathered collaborators for this book, we specifically looked for surgeons that were skilled at articulating their techniques in public. The authors chosen by the editors were those we operated with, moderated during live surgery, or personally observed teaching. This was to be a how-to book, focused on illustrating reproducible techniques. For each chapter there were specific objectives created by the editors and shared with

the authors. Multiple edits were made to make sure these objectives were met. Finally, all images and videos were reviewed to ensure the best learning experience possible. We recognize that we stand on the shoulders of giants. It is the hope of the editors and authors that we may help the next generation of urologists build their foundation for greatness and advancement in urologic upper urinary tract reconstruction. Finally, we must acknowledge all of our spouses and those that support us. For it is their unwavering and unconditional love that has allowed us to dedicate the time and effort to create this textbook.



Why Robotic Surgery?

1

Sunil H. Patel, Thomas W. Fuller, and Jill C. Buckley

History of Robotics in Urinary Reconstruction

The first application of a robotic platform for surgery was the PUMA 200 robotic arm in a neurological procedure in 1985 [1]. Robotics in urology began in earnest 15 years later with the approval of the da Vinci® robotic system by the Food and Drug Administration (FDA) in 2000 (Fig. 1.1). The same year the first robotic-assisted radical prostatectomy (RALP) was performed followed closely by a radical nephrectomy in 2001 [2].

Robotics was applied quickly thereafter to upper urinary tract (UUT) urologic pathologies. The first series reported robotic pyeloplasty was published in 2002 [3]. From 2002 to 2006, a wider variety of reconstructive robotic surgeries were described. A retrospective review over this period describes the expanded use of robotics to ureteroureterostomy and ureteral reimplantation [4]. After only a decade of robotics in urology, a large proportion of common urologic cases were being done robotically. In 2009, 10.2% of pyeloplasties were performed laparoscopically, 44.7% were performed open, and 45.1% were robotic assisted [5]. In 2012, a large retrospective series of 759 patients compared outcomes of laparoscopic or robotic pyeloplasty. Results showed improved success rates and decreased need for the secondary procedure with the robotic platform over laparoscopic surgery [6].

Lower urinary tract reconstruction closely followed robotic pyeloplasty. An initial small comparison of open (n = 41) versus robotic (n = 25) ureteroneocystostomy showed comparable success rates between modalities. The robotic approach had decreased hospital stays, narcotic pain requirements, and estimated blood loss [7]. In a series of 14 patients, the feasibility, safety, and efficacy of robotic-assisted bladder neck reconstruction were also established. There was a 75% patency rate and

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Fig. 1.1 The da Vinci® robotic system – fourth generation [23]



an 82% maintenance of continence at the 1-year follow-up. In addition, there were decreased blood loss and hospital stay compared to open perineal series [8].

Most recently, reconstructive surgeons have addressed ureteral strictures and rectourethral fistulas using the robotic platform. In a small case series, Zhao et al. described four patients undergoing ureteral reconstruction with buccal grafts. There were no intraoperative complications nor stricture recurrence at 15-month follow-up [9]. Chen et al. studied the management of rectourethral fistulas (RUF). They compared approaches including transperineal, transsphincteric, transanal, and transabdominal. The transabdominal approach was associated with greater morbidity and poor visualization [10]. The introduction of a minimally invasive surgical approach decreased patient morbidity and allowed for better visualization and suture placement deep in the pelvis [11].

Urinary Tract Reconstruction: Improved Visualization, Access to Narrow Anatomic Spaces, and Ergonomics

Robotic surgery improves both surgeon visualization and ergonomics. Muscle activation during robotic procedures is reduced compared to laparoscopic cases which decreases surgeon strain and fatigue. In a comparative assessment of ergonomics

in robotic versus laparoscopic tasks by measuring upper arm EMG activity, it was demonstrated that robotic surgery was ergonomically favorable compared to laparoscopy [12]. This has translated to a decrease in musculoskeletal pain in urologists based on a survey of physician members of the Endourological Society and Society of Urologic Oncology [13].

Robotic surgery optics also provide a clear, magnified, three-dimensional image. Areas such as the deep pelvis where RUF and vesicourethral anastomotic stricture repairs are performed have visual limitations in open procedures. The system provides digital magnification (10–15×), 3D high-definition (HD) images, and motion scaling allowing for visualization superior to that of open or laparoscopic procedures.

The seven degrees of motion, which imitates the dexterity of the human wrist in small spaces, allows for accurate and precise dissection and suturing in narrow and challenging spaces [14]. This precision and enhanced visualization in a comfortable sitting position are major advantages over open surgery and make robotic-assisted complex genitourinary reconstruction ideal.

Technological Advances

Near-Infrared Fluorescence

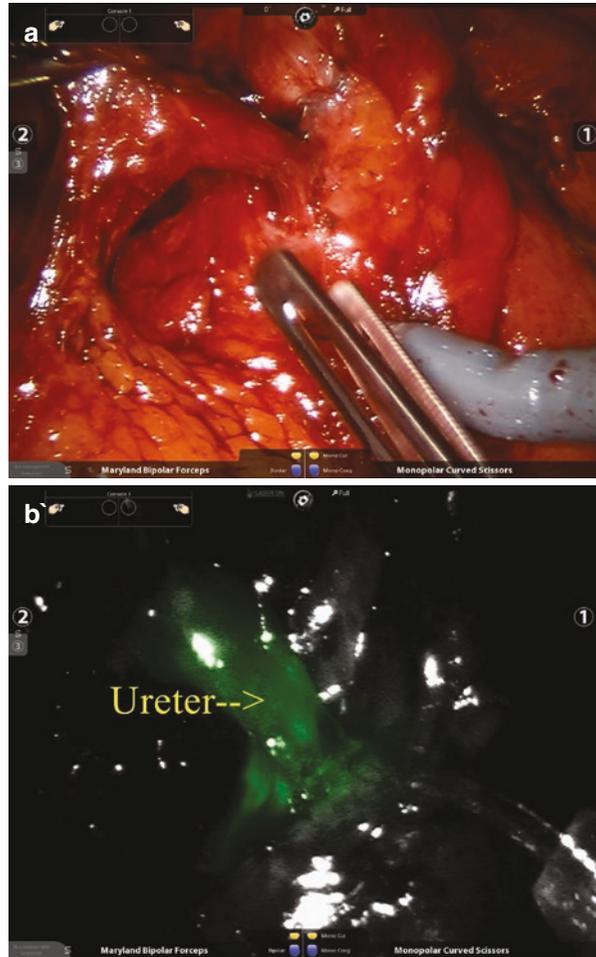
Near-infrared fluorescence (NIRF) with indocyanine green (ICG) allows the identification of vascular structures or urinary luminal structures. Selective renal artery clamping with NIRF has been shown to improve short-term renal functional outcomes compared to a partial nephrectomy without selective arterial clamping [15, 16].

NIRF in urinary reconstruction can be helpful for identifying urinary tract structures such as the ureter or renal pelvis in the initial reconstruction, but its true value is in the ability to identify these structures in redo cases with severe scarring. Additionally, it can be helpful to identify both viable and nonviable tissue in the ureter or with bowel by demarcating perfused versus devascularized tissue (Fig. 1.2) [17, 18].

Single-Port Robotic Surgery

Single-port procedures, also known as laparoendoscopic single-site (LESS) surgery, was first described in urology in 2007. Raman et al. performed three LESS nephrectomies using a single transumbilical incision [19]. Shortly after in 2009, the first robot-assisted LESS (R-LESS) surgeries were reported by Kaouk et al. who performed a pyeloplasty, radical nephrectomy, and radical prostatectomy [20]. The Cleveland Clinic recently corroborated this experience in 2018 publishing a report of two single-port robot-assisted radical prostatectomies (Fig. 1.3). The surgeries were successful with no complications or deviations from standard postoperative care [21].

Fig. 1.2 Intraoperative images of a redo robotic-assisted pyeloplasty highlighting the identification of the ureter after luminal injection of ICG (b) in a field of dense scar tissue (a)



TilePro™

TilePro™ is a multi-image display mode of the da Vinci® surgical system that allows for a picture in picture display on the surgeon console. In genitourinary reconstruction, it is indispensable in rendezvous procedures such as when a cystoscope or ureteroscope is used to demarcate fistulous tracts, to identify obliterated lumens, or to help identify the optimal location for ureteral reimplantation in continent urinary diversions. Figure 1.4 shows the utility of TilePro™ by identifying the location of an obliterated bladder neck with the use of the cystoscopy using the screen in screen TilePro™ technology.

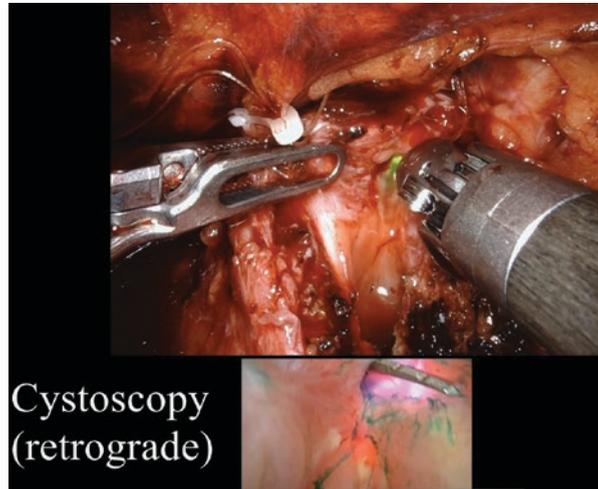
Fig. 1.3 The da Vinci® robotic single-port platform [23]



Simulation

The da Vinci® robotic platform provides new adopters of robotic technology and trainees with a simulation package. Simulation has been shown to have a positive correlation with intraoperative performance. Fundamental inanimate robotic skills task (FIRST) and da Vinci® skills simulator (dVSS) virtual reality task performance has been shown to correlate with intraoperative prostatectomy performance [22]. The authors of this study advocated for standardizing robotic simulation in training curriculums.

Fig. 1.4 Intraoperative image of the use of TilePro™ during an obliterated bladder neck reconstruction using cystoscopy to identify the site of the true lumen



Conclusion

Robotic operative technology is advancing steadily and will continue to play an important and expanding role in urologic surgery and genitourinary reconstruction in particular. Data is rapidly emerging for its utility and benefit in a wide variety of complex urinary tract reconstruction procedures. Shorter hospital stays, decreased narcotic requirements, and earlier return to work are all patient benefits that have been shown with the robotic platform. Improved visualization, ergonomic comfort while operating, and access to deep narrow spaces improve the surgeon experience. As a combined result, the penetrance of robotics in reconstruction will likely increase in the years to come.

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Part II

Keys for Intraoperative Success: Principles of Urinary Tract Reconstruction

Michael D. Stifelman

In these three introductory chapters we tackle the use of stents vs. nephrostomy tubes in managing patients with upper urinary tract obstruction. We review the principals of reconstruction with a focus on assuring adequate blood supply, improving wound healing and techniques of appropriate spatulation. In addition we dedicate an entire chapter to tissue substitution, an ever evolving field. These chapters will lay the foundation for all following techniques represented in this book and provide the nuances required to perform successful robotic urinary tract reconstruction.



Ureteral Stenting and Percutaneous Nephrostomy Drainage for Urinary Tract Reconstruction

2

Shaun E. L. Wason and Egor Parkhomenko

Ureteral stents relieve obstruction, promote healing, and provide a diversion for urinary drainage [1, 2]. In our practice, we place a double-J stent for all reconstructive upper and lower urinary tract procedures with a ureteral anastomosis. In the pediatric literature, ureteral stents have been shown to decrease hospital stay and reduce postoperative complications following a pyeloplasty [3–5]. Recent literature, however, has challenged the benefit of ureteral stents in pediatrics for reconstructive procedures, and stentless/tubeless procedures have been described [6, 7]. In this population, ureteral stent placement tends to be based on surgeon preference. Although the advent of the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA) has greatly facilitated intracorporeal suturing, obviating the need for stenting in certain patients, in our opinion; however, the risks of stent placement is less than the risk of a urine leak or disruption of the anastomosis.

There is no clear consensus regarding the optimal timing of ureteral stent placement during pyeloplasty. Preoperative retrograde ureteral stent placement has the advantage of ensuring that a stent of ideal length has been correctly placed; however, it requires an additional procedure and may obscure the obstructing segment intraoperatively, and a decompressed redundant pelvis can occasionally lead to a challenging dissection. Furthermore, excision of the strictured segment and reconstruction may be more difficult in the presence of a pre-placed stent. For these reasons, we routinely place ureteral stents in an antegrade fashion intraoperatively.

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The primary purpose of placing a percutaneous nephrostomy tube or ureteral stent is to relieve ongoing obstruction and alleviate symptoms. If a patient is obstructed but remains asymptomatic, we will typically proceed directly to the operating room for elective repair without a pre-placed nephrostomy tube or stent. In cases where the patient is obstructed and symptomatic, our preference is to place a percutaneous nephrostomy tube preoperatively, rather than a ureteral stent, in order to minimize periureteral inflammation, which can make the ureteral dissection more challenging. If a patient already has an indwelling ureteral stent in place, our practice is to exchange it for a nephrostomy tube 10–14 days prior to surgery.

The most common stent that we use in our practice is the Percuflex double-J stent (Boston Scientific, Boston, MA) with a hydrophilic coating, which facilitates placement intraoperatively. The short duration of stenting and the flexibility of silicone stents and a tapered tip make this ideally suited for reconstructive procedures. Other less common stent materials are biodegradable and metallic. Biodegradable stents have encountered difficulty with varying degradation rates, the need for a follow-up removal procedure and fragments entering the ureteral wall causing an inflammatory reaction [8–10]. New materials such as Uripren® are actively being pursued to tackle these challenges [11]. Metallic stents have been employed for select cases of high-grade compressive ureteral obstruction due to malignancy [12]. Recent studies have utilized metallic stents for both malignant and benign causes of ureteral obstruction but with varying success for benign pathology [13, 14]. Urologists have yet to adapt the use of metallic stents to common practice, and further data is needed to outline the benefit of metallic stents over the commonly used silicone stents. The rigidity of the metallic stent, in addition to the need for a sheath and fluoroscopy for placement, makes this stent less ideal for benign reconstructive procedures.

The choice of a larger or smaller diameter stent remains controversial. The former may compress and compromise the vasculature of the ureter and promote fibrosis, while the latter may not provide adequate drainage through the lumen of the stent. Moon et al. investigated the use of 7F and 14F stents in pigs and concluded that there were no differences in outcomes such as stricture formation [15]. Given this, the selection of ureteral stent diameter is surgeon dependent, and in our practice, we have adopted the use of either 6F or 7F stents exclusively.

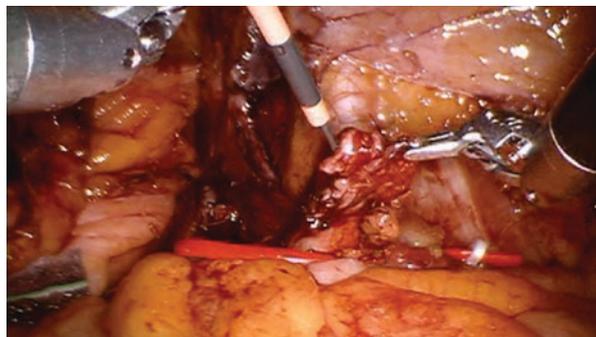
We typically use a fixed-length double-J stent chosen based on the length of the ureter from CT urography or retrograde pyelography or estimated based on a patient's height [16]. We will also typically err on the side of choosing a longer stent in order to minimize the risk of stent migration often found with short ureteral stents. For instance, if the ureteral length measures 26 cm; then, we will often place a 28 cm stent. This also ensures that the proximal curl rests in the upper pole of the kidney away from the neoureteropelvic junction anastomosis. In select situations, such as ureteral reconstruction in a transplant or pelvic kidney, we will employ a 4.7F double-J stent as these are more commonly available in shorter lengths at our institution.

Placing a double-J stent across the anastomosis is either done in an antegrade or retrograde fashion. The antegrade approach has been shown to yield lower operative times and is the preferred technique in a recent multicenter review as well as

in our practice [17, 18]. The timing of stent placement is at the discretion of the surgeon; however, the authors typically place the stent after half the anastomosis is complete. For antegrade stent placement during pyeloplasty, once the posterior anastomosis is complete, a stent pusher is placed through any sized port and directed down the ureter with the robotic needle drivers. Gentle manipulation is necessary to avoid excessive compression of the stent pusher. An angled 0.038in glide wire is passed through the stent pusher and directed down the ureter. An angled glide wire is used so that the floppy end curls within the bladder, and there is less risk of extrusion from the urethra. The pusher is held a few centimeters from the ureter to visualize the passage of the wire, ensuring resistance is not encountered early. At the point of resistance, the glide wire is grasped with the robotic needle drivers, and the stent pusher is removed. The double-J stent is passed with the tapered end over the guidewire. A hemostat forceps may be applied extracorporeally to hold the guidewire taut. Once the end of the stent reaches the robotic needle drivers, the console surgeon advances the stent antegrade down the ureter toward the bladder using a hand-over-hand technique. The stent is advanced until the proximal end is visualized, at which time the stent is stabilized, the guidewire is removed, and the proximal end of the stent is allowed to curl. The proximal curl can then be placed into the renal pelvis or an upper pole calyx, and the reconstruction can be completed. In the cases where there is no assistant port, a 14F intravenous cannula (angiocatheter) can be placed transcutaneously to allow passage of the guidewire and stent. To confirm stent placement, some centers have advocated filling the bladder with saline or methylene blue and clamping the foley so that the bladder is distended at the time of stent placement [19]. Reflux of fluid through the stent holes helps confirm appropriate placement. Other techniques to distend the bladder include clamping the foley 1 hour prior to stent placement and administering intravenous furosemide. We have found that this step is not always necessary unless there is a concern for a malpositioned stent.

For retrograde intracorporeal stent placement, as needed during a ureteroneocystostomy, stent placement can proceed in a similar fashion to that as previously described (Fig. 2.1) [20]. The console surgeon advances the stent toward the kidney

Fig. 2.1 0.038in Glidewire is advanced through the stent pusher into the distal ureter at the time of ureteroneocystostomy



until the distal curl is visualized (Fig. 2.2), the guidewire is removed, and the distal curl is placed into the bladder, and reconstruction can be completed (Fig. 2.3). Our technique is outlined in Video 2.1.

The less common, retrograde technique for ureteral stent placement requires pre-placement of either a 5F or 6F ureteral catheter into the proximal ureter with a flexible cystoscope. The ureteral catheter is prepped into the sterile field so that it can be manipulated by the bedside assistant at the time of stent placement. The guidewire can be passed through the ureteral catheter and is visualized intracorporeally entering the renal pelvis. The ureteral catheter can then be exchanged for an appropriate length stent over the guidewire. The stent pusher is subsequently passed over the wire, and the stent is advanced under direct vision by the console surgeon. Once the proximal curl is visualized, the stent is stabilized, and the wire is removed. A flexible cystoscope can be passed into the bladder to ensure an appropriate distal coil in the bladder.

Occasionally, intracorporeal stent placement will require manipulation of the stent both proximally and distally during ureteroureterostomy for mid-ureteral repair. In this scenario, the guidewire is passed through the stent directly to straighten one end of the stent. We usually pass the stent in a retrograde fashion toward the kidney first. The stent is stabilized, and the wire is removed. The entire stent is left intracorporeally, and the guidewire can be inserted through a side hole of the stent

Fig. 2.2 The double-J stent is advanced by the console surgeon over the guidewire into the kidney

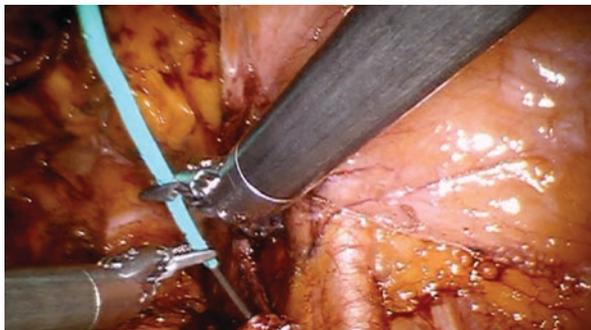


Fig. 2.3 The guidewire is removed, and the distal end of the stent is curled. A video of our technique for robotic intracorporeal double-J stent placement for urinary tract reconstruction is included



by the console surgeon until the distal curl is straightened. The distal end can be passed antegrade down the ureter into the bladder, and the guidewire is removed. We confirm stent placement with flexible cystoscopy at the end of the case as it is easy to do and the most reliable; however, a plain abdominal radiograph on the operating room table or a bedside ultrasound is also acceptable.

We typically remove ureteral stents 3 weeks after any reconstructive procedure involving the collecting system. However, in the literature, the ideal stent duration remains controversial. Kerbl *et al.* compared the effects of stent duration at 1, 3, and 6 weeks after an endoureterotomy in pigs and found favorable results in ureters stented for only 1 week [21]. A stent is thought to allow for regeneration of the ureter through a diversion of the urine while providing a platform upon which the ureter can heal [1, 2]. Yet, as a foreign body, ureteral stents can cause inflammation of the native tissue and predispose to infection [22]. Recently, Danuser *et al.* evaluated the efficacy of 1-week vs 4-week stent duration after a laparoscopic or robotic-assisted pyeloplasty. They found no significant differences between the two groups with respect to obstruction and concluded that 1-week stent duration is comparable to 4 weeks [23]. Nevertheless, there is a paucity of evidence for the optimal stent duration in humans, and thus, the final decision remains in the hands of the surgeon.

Ureteral stents have served as excellent tools for assisting in urinary diversion and ureteral healing for an assortment of urological procedures, but their use is not without morbidity. As temporary indwelling foreign bodies, they have been associated with urinary frequency, incontinence, hematuria, pain from daily activities, sexual dysfunction, infection, and encrustation [24]. Several treatment modalities have been explored to mitigate stent-related symptoms. Both alpha-blockers and anti-muscarinics alone or in combination have been used to successfully improve stent-related symptoms as assessed by the Ureteral Stent Symptom Questionnaire (USSQ) [25–27]. In the literature, nonsteroidal anti-inflammatory drugs (NSAIDs) have also been documented to improve renal colic [28]. Of note, a single dose of an NSAID prior to stent removal has been shown to reduce pain associated with stent removal and reduce the need for opioid analgesia [29]. Another commonly used analgesic that concentrates in the urine, phenazopyridine, can be used for dysuria, but recent studies have questioned its efficacy in improving USSQ scores [30]. Finally, a newer medication, pregabalin, in a recent randomized prospective study has shown an improvement in USSQ scores, particularly quality-of-life measures, as a stand-alone medication for patients with indwelling ureteral stents [31]. In our practice, intraoperative ketorolac (15 mg or 30 mg IV) is routinely employed following ureteral reconstructive procedures, barring any medical contraindication or renal insufficiency. Postoperatively, pain is managed using a combination of alpha-blockers, NSAIDs, acetaminophen and phenazopyridine with judicious oral narcotics (oxycodone 5 mg) for severe breakthrough pain, with a trend toward eliminating narcotics altogether.

Another common complication of ureteral stent utilization is the predisposition to infection. Farsi *et al.* have shown that indwelling ureteral stents are colonized within a few weeks [32]. A publication by Nevo *et al.* indicates that sepsis rates increase dramatically beyond the first month of ureteral stent placement [33]. Thus,