Review Article

Robotic assisted reconstruction for complications following urologic oncologic procedures

Daisy Obiora, Hailiu Yang, Ronak A. Gor

Division of Urology, Department of Surgery, Cooper University Health Care, Cooper Medical School of Rowan University, Camden, NJ, USA

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Correspondence to: Ronak Gor, DO. Division of Urology, Department of Surgery, Cooper University Health Care, Cooper Medical School of Rowan University, 3 Cooper Plaza Suite 411, Camden, NJ 08103, USA. Email: gor-ronak@cooperhealth.edu.

Abstract: Despite technical refinements in urologic oncologic surgery, complications are inevitable and often carry significant morbidity. Similar to oncologic surgery, reconstructive surgery has realized a paradigm shift from mainly open to an increasingly minimally invasive approach. Robotic assisted surgery has facilitated this transition as it mitigates some of the limitations of traditional laparoscopy. With continued technological advances in robotic technology along with improved training and experience, the breadth and complexity of cases expand annually. Few head to head trials exist and data is overall heterogeneous. Herein, we review and summarize the currently available literature describing robotic assisted reconstruction for complications following urologic oncologic procedures.

Keywords: Bladder neck contracture (BNC); robotic reconstruction; cancer survivorship; ureteroenteric anastomosis stricture (UEAS); ureteral stricture

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Introduction

Reconstructive urology, once a relatively small subspecialty primarily focused on urethral reconstruction and trauma, has blossomed into a robust, encompassing entity at the forefront of innovation and technology. Urologists were the first adopters of the robotic surgical platform, which is well suited for deep pelvic surgery, serving as a natural progression for radical prostatectomy, such that, the transition from open to robotic assisted laparoscopic prostatectomy (RALP) has been swift and nearly universal in the United States. Since then, urologists have pushed the robotic envelope, expanding the breadth and depth of indications for oncologic surgery, such that nearly all urologic malignancies may be treated via a minimally invasive approach.

In both open and minimally invasive urologic oncologic surgery, complications occur in the best of scenarios and often require the use of reconstructive surgery. Issues are typically obstructive in nature and may occur anywhere along the urinary tract. Patients are often complicated by intra-abdominal adhesions, altered anatomy and radiation damage. Historically, large open incisions were required for adequate exposure, however, as the robotic platform and surgeon training have evolved, an increasing number of procedures are performed via a robotic assisted approach. Herein, we discuss the contemporary use of robotic assistance in the treatment of complications following urologic oncologic procedures.

Methods

A literature review utilizing PubMed was performed employing multiple search terms relevant to the current topic. A number of references were evaluated and reviewed by three separate Urologists for quality of evidence and relevance to the topic in question. Non-English language sources were excluded resulting in a final number of 44 resources that were included in this systematic review. Please note that a large number of the included resources are small retrospective series given the limited nature of evidence available on this topic, this serves as a limitation to this particular review, however larger retrospective data is unlikely to be forthcoming regarding this particular topic.

Prostate cancer

Prostate cancer is the most common non-cutaneous malignancy in men in the United States. Treatment options include radical prostatectomy (open or RALP), brachytherapy, external beam radiation, high-frequency ultrasound ablation, and cryotherapy, among others. All treatment options may lead to complications, from bladder neck contracture (BNC) to fistulae formation. In this section, we will discuss these complications and the evolving role of robotic surgery in addressing these complications.

BNC/stenosis

BNC is defined as the scarring and narrowing of the bladder neck/vesicourethral anastomosis. Following open radical prostatectomy, BNC was relatively frequent—greater than 10% in multiple reported experiences (1,2). CapSure data, a registry of 6.597 patients with biopsy-proven prostate cancer suggests an overall rate of 5.2% for all treatment groups and 8.4% in patients undergoing radical prostatectomy (3). Many consider the advantages offered by robotic prostatectomy, namely, improved deep pelvic visualization to allows for precise bladder neck tailoring and mucosal apposition, a contributing factor to the declining rates of BNC in more recent series (4,5).

Initial management of BNC include endoscopic approaches using laser, cold-knife, loop resection, balloon dilator and/or electrocautery. Reports of mitomycin or steroid injections after endoscopic treatment are also reported (6). Although short-term outcomes of endoscopic treatment are excellent, long term follow up data is lacking. BNC refractory to endoscopic management may require formal bladder neck reconstruction. Historically, open reconstruction was performed with a trans-abdominal, perineal, or combined approach. The same limitations for vesicourethral anastomosis during open prostatectomy present challenges during trans-abdominal reconstruction, occasionally requiring ancillary maneuvers such as pubectomy for exposure. Perineal or combination approaches typically result in stress incontinence, requiring subsequent high-risk anti-incontinence surgery performed in the setting of attenuated urethral integrity following multiple urethra-transecting procedures.

Robotic bladder neck reconstruction (RBNR) holds several advantages over open pelvic reconstruction, including increased articulation in a narrow working space, optimized visualization allowing precise suturing and decreased tremors. Typically, if the level of obstruction does not extend beyond that of the urogenital diaphragm, a perineal counter incision for urethral mobilization is unnecessary (7). Several groups have reported Y-V plasty outcomes in which the scar is incised on the anterior surface and a flap of bladder is advanced distally to increase the lumen diameter (8). Granieri *et al.* reported a single-surgeon series of 7 patients with BNC from photoselective vaporization of prostate, radiation therapy, and RALP. They reported 100% resolution with no major complications with a median follow-up of 8 months. Only 2 of 7 patients had incontinence after the procedure and pubectomy was not required (8). Theoretically, less urethral mobilization via a robotic assisted approach may allow for larger artificial sphincter cuff diameter, should it be necessary. It should be noted that only 1 patient had a previous RALP and no contracture was extensive enough to warrant a combined abdominoperineal approach. Kirshenbaum reported the trauma and reconstructive urologic network of surgeons (TURNS) multi-institutional experience of the RBNR (9). Of the 12 patients who underwent RBNR, five patients had BNC from RALP and 7 from endoscopic procedures. Three of 12 (25%) patients recurred, defined as less than 17 Fr lumen on cystoscopy. Limitation of this study was that it was a retrospective study with short follow-up (13.5 months) and patients who had radiation therapy or required abdominoperineal approach were excluded. Musch *et al.* [2018] reported 12 patients who underwent a Y-V plasty for refractory BNC at a single institution in Germany. They reported an 83% success rate at median follow-up of 2 years without major complications. Unfortunately, 10 of 12 had initial procedures for benign prostatic disease and the other 2 patients had high-frequency ultrasound ablation. In this study, only 1 patient had *de-novo* stress incontinence (10). To date, there is a single report of robotic combined abdominoperineal BNC repair (11). This patient had a 4.5 cm defect after a complicated open radical prostatectomy. In this report, the bulbar urethra was mobilized via perineal approach while the bladder was mobilized robotically via the abdominal approach. The distal urethra was then passed into the pelvis and the vesicourethral anastomosis was performed robotically. The patient had a patent bladder neck at 12-month follow-up and stress incontinence of 1 pad per day.

In patients with radiation induced posterior urethral stenosis this presents a particular challenge as salvage prostatectomy may be required. If the stenosis extends beyond the external sphincter, a combined robotic-perineal approach is typically required, mobilizing the urethra into the pelvis. Buccal mucosa graft may be utilized for non-obliterated stenosis. Data from these series are pending.

Preliminary outcomes are promising for RBNR. However, significant literary heterogeneity exists both in etiology of BNC and definition of success. Prospective multi-institutional prospective studies with robust follow-up are needed but given the relative scarcity of the procedure, this data may not be available soon.

Recto-urethral fistulas (RUFs)

RUFs are rare, devastating complications of both surgical and ablative treatment of prostate cancer. Fistula formation after a prostatectomy may result from unrecognized bowel injury and/or urine leak. Radiation history is often present as well. Fistula formation after an ablative treatment is usually a result of tissue ischemia and inflammation. While conservative management may be attempted in non-complicated cases, most require surgical repair. There have been many reported approaches of fistula repair, nearly all of which require open surgery. A variety of approaches to RUF repair are described with open approaches dominating the experience (12). Trans-abdominal repair was required in only 20% of cases. Evidence for robotic transperitoneal RUF is limited to case reports (7,13-15). All 4 reported successful fistula repair with multi-layer closure plus tissue interposition (2/4) or temporary bowel diversion (1/4). Experienced robotic reconstructive urologists today are performing these cases routinely with outcome data pending.

Transanal RUF repair is an evolving arena where robotic surgery may play a role. Laparoscopic transanal fistula repair has been described via a single-port placed in the anus (16,17). The limitations of this type of surgery are similar to those of traditional laparoscopic prostatectomy. The newly FDA-approved da Vinci SP platform (Sunnyvale, CA, USA) may mitigate these limitations, offering more approachable method of minimally invasive repair.

Reconstruction after urinary diversion

Complications after radical cystectomy with continent/non-continent urinary diversion are common in both the immediate and delayed setting (18,19). Complications requiring reconstructive surgery are typically borne from the urinary diversion. Ureteroenteric anastomosis stricture (UEAS) is relatively common after urinary diversion and may present at any point after surgery. When followed for extended periods after surgery, UEAS rates are reported as high as 19% (20).

On initial presentation, patients are usually treated with either a ureteral stent or nephrostomy tube for immediate decompression and characterization of the stricture. Poor surgical candidates or those not willing to undergo major reconstruction will remain with indwelling stents and nephrostomy tubes. Similar to traditional endoscopic ureteral surgery, endoscopic approaches have little morbidity, however, long-term outcomes are poor. Many patients continue to rely on indwelling stents or nephrostomy tubes. Open ureteral reimplant is considered the standard of care, with reported success rates of 90% in select series (21). Challenges of the open approach include dense intra-abdominal adhesions, limited visualization, adherence of the conduit to retroperitoneal vasculature and tenuous tissue for repair.

Robotic UEAS repairs have been reported in by several institutions with acceptable outcomes. Dangle and Abaza [2012] reported two patients who had successful robotic unilateral ureteroenteric reimplant without complication with >2 years of follow-up (22). Tobis *et al.* [2013] reported 4 patients who had successful robotic unilateral UEAS repair with no complication at 16 months of follow-up (23). Gin *et al.* [2017] reported a large series of 41 patients with 50 units who underwent primary UEAS repair at a single institution. Five cases were performed robotically by 3 different surgeons and 37 open cases were performed a single surgeon. The authors reported a 100% rate of success at median follow-up of 16 months with an overall 30-day complication rate of 33%, of which 2.3% were major complications. Multi-variable analysis of variance found that robotic approaches were associated with decreased length of stay (3.2 *vs.* 6.4 days) without increased complication or failure rates (24). Ahmed *et al.* [2017] reported what is, to date, the largest series of minimally invasive UEAS revision with 16 patients receiving robotic and 6 receiving open revision. Contrasting previous reports, the authors did not find a length of stay benefit and noted increased intraoperative (13% *vs.* 0%; P=0.04) and major (23% *vs.* 0%; P=0.04) complications (20).

Several novel techniques have recently been reported for robotic UEAS repair. Padovani *et al.* [2017] recently reported a series of 3 cases of ureteroileal bypass surgery, 1 of which was performed robotically (25). Instead of dissecting out and redoing the previous anastomosis, the authors performs a 1 cm side-to-side anastomosis using a more proximal segment of the ureter. This approach mirrors the non-transecting ureteral reimplant for traditional distal ureteral injury/obstruction. The authors reported a mean operative time of 120 minutes, no complications, and 100% success rate with a mean follow-up of 29.3 months (25). Lee *et al.* [2018] reported 8 patients with 10 renal units who underwent robotic UEAS revision with the assistance of indocyanine green (ICG) (26). ICG was injected through a retrograde ureteral catheter and/or nephrostomy tube (if present). The area of ureteral narrowing was identified by its lack of fluorescence (*Figure 1*). This technique allowed the authors to characterize the stricture(s) and determine the proper procedure. There were 3 (37.5%) minor and 2 (25%) major complications (bilateral pulmonary emboli and ureteral stent dislodgement requiring nephrostomy placement). The median length of stay was 6 days. 80% of the renal units remained disease-free radiologically and clinically with a mean follow-up of 29 months (26).

In summary, robotic reconstruction may help post-cystectomy patients with benign UEAS avoid the morbidity of repeat laparotomy and open reconstruction. Robotic surgery offers improved visualization, precise suturing and tools such as ICG, which can be used intra-luminally for identification of structures or intravascularly to confirm tissue quality before anastomosis (26). In our experience, robotic approaches with Trendelenburg positioning along with intraureteral ICG offers rapid ureteral identification, consolidates dissection time and significantly reduces surgeon fatigue. Long term, multi-institutional outcomes will help confirm the role of robotic surgery in these cases.

Reconstruction after upper tract urothelial carcinoma (UTUC)

Although the majority of complications requiring reconstruction following urologic oncologic surgery occur in the pelvis, complications requiring reconstruction may present when kidney sparing approaches are employed when treating UTUC. Open approaches are effective, but they carry significant morbidity including prolonged hospital stay, increased blood loss and high analgesic requirements (27). As laparoscopy gained traction in the 1990's into 2000's, pioneers in the field made significant advances. Steep learning curves, cumbersome ergonomics and long operative times prevented universal penetration of laparoscopic ureteral reconstruction in contemporary practice (27). Robot-assisted laparoscopy, in part, mitigates these issues, resulting in a more approachable option for surgeons (28).

Ureteral reconstruction after segmental ureterectomy

Complications may arise from the ureteroneocystostomy during segmental ureterectomy, namely, stenosis resulting in obstruction. Ureteral reimplantation with or without ancillary maneuvers such as psoas hitch and Boari flap have become mainstays in the therapy of iatrogenic and traumatic ureteral injuries (29). When combined with psoas hitch and Boari flap, upwards of 20 cm of ureteral length may be accounted for (30). Preoperative assessment mirrors that of the open approach, in that accurate assessment of length and location of the obstruction, bladder capacity, radiation history, and surgical history are accounted for. Combination antegrade and retrograde ureteropyelography, in our opinion provides the most accurate assessment of the length and location of obstruction. Port placement is similar to laparoscopic prostatectomy, however, shifting the instruments cephalad a few centimeters may facilitate more proximal ureteral work.

Surgical principles parallel those of open surgery including minimizing adventitial dissection from the ureter, exposure of the psoas minor tendon and robust mobilization of the bladder. Sacrificing the contralateral vascular pedicle is not usually indicated, however, may be employed if necessary. Boari bladder flap further bridges the gap if the ureter does not easily lay on the bladder without tension following psoas hitch alone. Care should be taken to ensure the width of the flap is sufficient to prevent flap ischemia after tubularization (30,31). Anastomosis may be performed in a refluxing or non-refluxing fashion. Hemal *et al.* reviewed 44 cases of ureteral reconstructions, of which, 18 involved the distal ureter where reimplant with or without bladder flap were employed (28). They note favorable operative times, length of stay, blood loss, with success noted at 10 months (28,32).

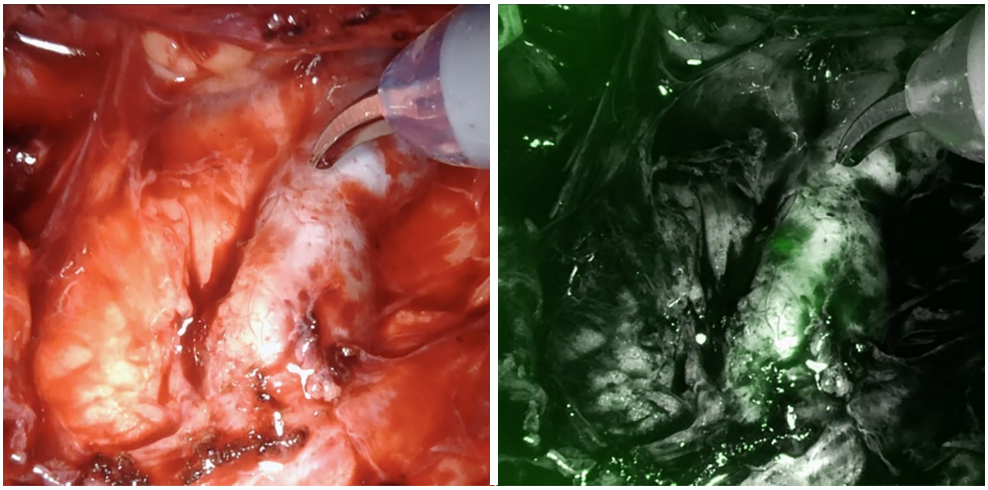

Figure 1 Intraureteral ICG facilitating ureteral identification and stricture location (used with permission from Lee Zhao, MD). ICG, indocyanine green.

Ureteral reconstruction with buccal graft

In cases where ureteral mobilization or inadvertent injury leads to more proximal ureteral obstruction, buccal mucosa grafts may be used to repair the ureter. Urologists readily use buccal mucosa for urethral reconstruction due to its ease of accessibility, minimal morbidity and favorable histologic characteristics that allow for graft take. Pioneering surgeons realized the potential application of buccal mucosa in upper urinary tract reconstruction and this was first used in humans for ureteric defects in 1999 by Naude (33). Kroepfl and colleagues reported a successful series of 7 patients with upper tract reconstruction via an open approach (34). More recently, Zhao and colleagues published a multi-institutional series of 19 patients of which 3 were robotic buccal ureteroplasties (RBU) performed on patients with proximal to mid ureteral strictures measuring <5 cm not amenable to ureteroureterostomy, demonstrating efficacy, safety and efficiency (35).

Techniques are well described with key points involving positioning that allows for simultaneous access to the oral cavity, abdomen and genitalia (35,36). A modified flank approach using stirrups may facilitate positioning (*Figure 2*). Intraureteral ICG may be instilled in instances where the ureter may not be readily visible. Principles for ureteroplasty mimic those of urethral reconstruction. Namely, dorsal or ventral ureterotomy along the entire length of the stricture into healthy ureter, minimal ureteral mobilization, graft placement with dorsal support of the psoas muscle, or an omental or local adipose wrap if ventral. Similar to urethral reconstruction, if a completely obliterated lumen is encountered, this region is excised and an augmented anastomotic ureteroplasty may be performed, reducing the mobilization requirements (35,36).

The appendix has a rich history in urologic reconstruction, functioning as the preferred continent catheterizable channel for decades. Appendiceal ureteral substitution was first reported in 1912 by Melnikoff as an interposition graft (37). Since then, its use in the pediatric and adult population has been reported predominantly in the management of short segment right-sided ureteral strictures >1.5 cm in length (38-42). In cases where bladder size or history of radiation may preclude bladder flap, appendiceal interposition may be employed. Although it technically can be used bilaterally, its location is optimized for right sided reconstruction. Reggio *et al.* described laparoscopic appendiceal onlay with acceptable outcomes at a mean follow up of 16 months (43). The relative metabolic silence of the appendix obviates the electrolyte derangements that may occur using small bowel, all while avoiding a bowel anastomosis. The employment of an onlay graft as opposed to an interposition is particularly useful as it limits the potential of ureteroappendiceal strictures or leaks at the anastomotic sites due to the small caliber of the appendix (40,43). Eun and colleagues presented their approach to appendiceal interposition and recently published report of appendiceal interposition with lower pole calycostomy, downward nephropexy and psoas hitch (44).

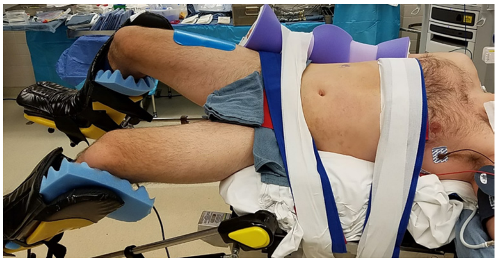

Figure 2 Modified flank positioning for upper urinary tract reconstruction. Appendiceal Ureteral Reconstruction

The future of robotic reconstructive urologic surgery

In the best of hands, reconstructive procedures after oncologic surgery are challenging. Physicians must be cognizant that although complications after oncologic surgery may occur, patients, despite informed consent, do not anticipate these obstacles. The physical, emotional and financial burdens of post-operative compilations must be recognized as patients may be burdened by drainage bags, become depressed, and experience loss of work/wages. Efforts to establish robotic reconstructive urologic programs must therefore be structured to mitigate even further complications. Surgeons must reflect on their training and comfort with robotic assisted surgery—if there is any concern, partnering with those more facile with robotic assisted surgery should be employed. If a collaborative approach is not feasible, then referrals to centers of excellence should be considered. As contemporary training programs evolve, such that, graduates may feel equally, if not more comfortable with robotic than open surgery, we may increasingly consider the robotic platform as an instrument used to accomplish a task, rather than an alternative approach to open surgery.

Conclusions

Herein, we highlight various attributes of the robotic system that render it an appealing tool for urologists to repair various complications after treatment of urologic malignancies with comparable outcomes.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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