Robotic Ureteral Reconstruction

Alice Drain, MD, MS[a], Min Suk Jun, DO, MS[b], Lee C. Zhao, MD, MS[a,*]

KEYWORDS

• Robot • Ureteral stricture • Ureteral reimplant • Ureteroureterostomy • Buccal mucosa • Appendiceal flap • Ileal ureter • Retrocaval ureter

KEY POINTS

- Ureteral strictures should be approached with an algorithmic model with decision of reconstructive technique determined by location, length, and grade.
- Preoperative evaluation after ureteral rest with antegrade and retrograde ureterogram guides the treatment approach.
- Attention to preservation of ureteral blood supply is crucial; anatomic knowledge of the vasculature is critical, circumferential dissection should be avoided, and an onlay is preferred over interposition.
- Ileal ureter remains a salvage option if more minimally invasive techniques are not feasible.

INTRODUCTION

Increasingly sophisticated robotically assisted laparoscopic technology and techniques have led to significant advances in the minimally invasive treatment of ureteral strictures. Stricture etiologies include radiation, iatrogenic injury, trauma, urolithiasis, and congenitalism. Traditionally, ureteral strictures longer than 2 cm, which are refractory to endoscopic treatment, were treated with ureteroneocystotomy with or without psoas hitch or Boari flap, ureteroureterostomy (UU), ileal substitution, or autotransplantation.[1] Laparoscopic ureteral reconstruction was first described in 1992 by Nezhat and colleagues,[2] who performed a UU, but this procedure was not widely adopted owing to the technical challenges of the procedure, which requires dissection and precise suturing in a tight working space with limited exposure. Techniques for ureteral stricture repair were first adapted to the robot in 2003 when Yohannes and associates[3] performed a ureteral reimplantation with a Boari flap for a distal stricture. Middle and proximal ureteral strictures pose a greater challenge owing to both their location and etiology. The prevalence of robotic-assisted repair of mid and proximal ureteral strictures has increased greatly over the past decade with some now considering it the standard of care.[4,5] The robot's magnified view, stereoscopic vision, freedom of articulation, and availability of adjunct technology such as Indocyanine green and Firefly infrared laparoscopy are particularly advantageous in ureteral repair.[6,7] This article describes the latest advances in the robotic approach to ureteral stricture management.

DIAGNOSIS

Presenting symptoms of ureteral stricture are consistent with renal colic owing to upper tract obstruction, including flank pain, abdominal pain, nausea, vomiting, and pyelonephritis. A computed tomography scan is commonly performed, revealing hydroureteronephrosis with a distinct transition point along the ureter without another obvious cause for obstruction such as a ureteral calculus. In some cases, the obstruction can be asymptomatic and only incidentally found. Laboratory evaluation may reveal worsening renal

[a] NYU Langone Health Department of Urology, 11th Floor, 222 East 41st Street, New York, NY 10017, USA;
[b] Crane CTS, 575 Sir Francis Drake Blvd, Suite 1, Greenbrae, CA 94904, USA
* Corresponding author.
E-mail address: Lee.zhao@nyulangone.org
Twitter: @AliceDrainMD (A.D.); @DrMinJun (M.S.J.); @lee_c_zhao (L.C.Z.)

Urol Clin N Am 48 (2021) 91–101
https://doi.org/10.1016/j.ucl.2020.09.001

urologic.theclinics.com

function. When patients present acutely, a urologist will often place a ureteral stent for decompression. Some patients who would otherwise be good candidates for repair are managed with serial ureteral stent exchanges.

ANATOMY

The ureters run bilaterally starting posterior to the renal artery, anteriorly along the psoas muscle, posterior to the gonadal vessels, anterior to the bifurcation of the common iliac artery, and along the medial aspect of the internal iliac artery. The ureter then courses medially and runs with the hypogastric nerves into the endopelvic fascia, crossing anterior to the obturator artery, vein, and nerves. In men, the vas deferens loops medially over the ureter at this point, in females the ovary and more distally the uterine artery run anteriorly. In cases requiring distal ureteral mobilization, careful dissection of the hypogastric nerves at this point may help to preserve bladder function.[8]

The ureters can be divided into upper ureter, extending form the ureteropelvic junction to the upper border of the sacrum, the middle ureter, extending from the upper to the lower border of the sacrum, and the lower ureter, which travels from the pelvis to the bladder. There are important differences in blood supply to these 3 anatomic regions. The upper ureter is supplied by branches arising medially from the renal artery and occasionally the abdominal aorta or gonadal artery, the mid ureter posteriorly by branches off the common iliac arteries, and the distal ureter laterally by the superior vesical artery, a branch off the internal iliac artery. These branches further divide to form a longitudinal anastomotic plexus along the ureter, and it is important when determining the location for ureteral spatulation and graft onlay to be aware of arterial supply and minimize disruption. Clinically when determining approach to stricture repair, we divide the ureter into the proximal and mid ureter and the distal ureter with the distal ureter beginning when the ureter runs over the bifurcation of the common iliac artery at the pelvis, which corresponds roughly with the inferior edge of the sacroiliac joint on imaging. There is a normal anatomic narrowing at the levels of the ureteropelvic junction, iliac vessels, and ureterovesical junction, and this must be distinguished on imaging from stricture in preoperative evaluation.

PREOPERATIVE PLANNING

When there is suspicion for ureteral stricture, we recommend placement of a percutaneous nephrostomy tube. If a patient has previously been managed with an indwelling ureteral stent, the stent can be used as a target on imaging. Alternatively, a urethral catheter can be placed and the bladder instilled with irrigation, inducing hydronephrosis and providing a larger target for percutaneous access. At this point, the stent is removed allowing for a period of ureteral rest for 4 to 6 weeks, similar to the urethral rest described for anterior urethral strictures.[9] This period will allow for the ureteral stricture to fully declare itself.[6] After ureteral rest, a renal scan can be performed to assess function and confirm obstruction. Nephrectomy may be appropriate for kidneys providing less than 20% split function in the setting of recurrent pyelonephritis. After the period of ureteral rest, further imaging to visualize the location, length, and grade of stricture with an antegrade and retrograde ureterogram should be performed (**Fig. 1**). Ureteroscopy may be used to definitively rule out malignancy as the cause of obstruction. At this point, the diagnostic workup is complete, and the patient is counseled on the findings before definitive repair. A urine culture is collected and treated preoperatively as needed. The indwelling nephrostomy tube is a nidus for colonization, and patients are at higher risk of bacteremia, funguria, and sepsis. As such, antibiotic coverage is broadened as per the discretion of the surgeon and local guidelines. Routine bowel preparation is not recommended.

PATIENT POSITIONING

Women are placed in dorsal lithotomy with the ipsilateral side elevated. Men may be positioned in lateral decubitus. The genitalia and nephrostomy tube are included in the sterile field. The patient must be well-secured because Trendelenburg is often used in cases of distal stricture. The endotracheal tube is taped to the low side because the buccal graft is harvested from the top (ipsilateral) side. The mouth is prepped and draped separately if a buccal mucosal graft is needed.

PROCEDURAL APPROACH

i. Port placement (**Fig. 2**)
   - Obtain access at the midline, superior to the umbilicus.
   - Distal stricture: Robotic ports are placed similarly to a robotic cystectomy. The ports are placed sufficiently superiorly to allow for bladder manipulation.
   - Proximal or mid stricture: Robotic ports are placed vertically along the midclavicular line

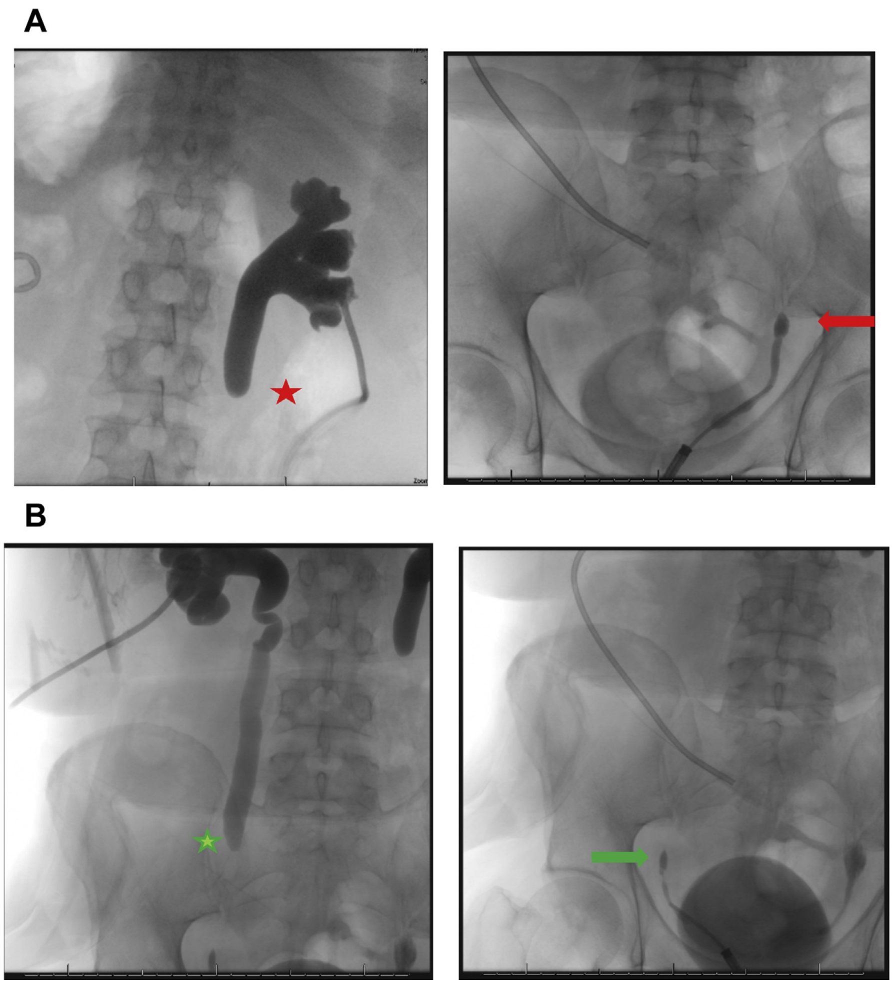

Fig. 1. Antegrade and retrograde pyelograms (*A*). Right ureter: approximately 10 cm stricture. Note moderate hydronephrosis and hydroureter to proximal ureter with abrupt termination (*star*) and narrowing of the distal ureter below pelvic brim (*arrow*). (*B*) Left ureter: approximately 4 to 5 cm stricture. Note severe hydronephrosis, and moderate hydroureter to mid ureter (*star*) with abrupt narrowing of the distal ureter below the pelvic brim (*arrow*). The patient was treated with right ileal ureter and left Boari flap.

starting 2 fingerbreadths below the costal margin to 2 fingerbreadths above the iliac crest. Port placement may be modified as needed based on the presence of adhesions.

ii. Instrumentation
   - Our preference is to use Maryland bipolar forceps, monopolar scissors, and ProGrasp forceps.
   - Camera: 30°

iii. Endoscopy
   - Flexible cystoscopy is performed and a guidewire placed in the ureter.
   - The flexible ureteroscope is advanced over the guidewire to the level of the stricture. TilePro (Intuitive, Sunnyvale, CA) is useful to enable the console surgeon to see the ureteroscopic view.

iv. Robotic dissection and identification of the stricture
   - The colon is medialized and the ureter is identified. We prefer to avoid circumferential ureterolysis to preserve blood supply. The iliac vessels lie posterior to the ureter, and normal planes are often obliterated in reoperative and irradiated fields. Avoidance of circumferential ureterolysis can minimize injury to these vessels.
   - Maneuvers that can aid in ureteral identification
     a. The Firefly (Intuitive, Sunnyvale, CA) camera can be used because it detects the near-infrared spectrum of the light

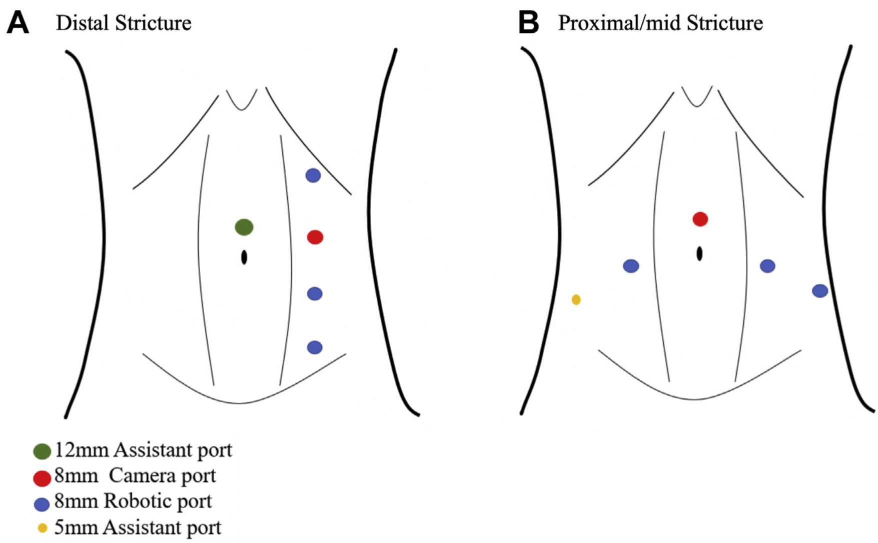

Fig. 2. Port placement.

emitted by the ureteroscope, which transmits through tissue more readily than visible light. Note that this will not work if a digital flexible ureteroscope is used because these scopes do not emit light in the near-infrared spectrum.

b. Indocyanine green (ICG) (25 mg ICG in 10 mL water) can be injected intraluminally via nephrostomy or in a retrograde fashion.[6] Of note, once in contact with urothelium, it will be present for the duration of the case, compromising its utility in assessing ureteral vascularity through intravenous (IV) administration.

v. Ureterotomy
- We prefer to make a longitudinal ureterotomy anteriorly to preserve blood supply when the ureteral lumen is patent. This is extended until normal caliber ureter is encountered. If the ureteral lumen is obliterated, the ureter is transected, and the distal and proximal ends are mobilized until the posterior wall can be reestablished in a tension-free manner.
- IV ICG (10 mL × 1 mg/1 mL) may be used to assess ureteral blood supply.[10,11] Within seconds of administration, well-perfused tissue will glow green under the near-infrared camera. If the proximal or distal extent of the ureterotomy is poorly vascularized, consider extending the ureterotomy until well-perfused ureter is encountered.

vi. Ureteral reconstruction
- A detailed discussion of techniques is provided elsewhere in this article.

vii. Stent placement
- A 6 Fr ureteral stent is placed over the wire before completion of the anastomosis.

viii. Evaluation of anastomosis
- Distal stricture: The bladder is instilled with 180 mL of saline to confirm a water-tight anastomosis.
- Proximal or mid stricture: Irrigation through the ureteroscope confirms a water-tight anastomosis. Alternatively, the bladder can be filled and reflux through the ureteral stent can confirm water-tight closure.

ix. Nephrostomy tube removal
- If no longer needed, the assistant should remove the nephrostomy tube while the ureteral stent is grasped to avoid accidental dislocation.

x. Drain placement
- A closed suction drain is placed near the anastomosis. This drain will be removed on postoperative day 1 if output remains low after Foley removal.

DISTAL URETERAL RECONSTRUCTION

Ureteral Reimplantation

Distal ureteral strictures may be managed with ureteral reimplantation. Traditionally, the ureter is circumferentially dissected and a vessel loop is passed to isolate it. The distal ureter is mobilized to facilitate a tension-free anastomosis. The ureter is transected proximal to the stricture. The bladder is then filled with 200 to 300 mL of saline and a cystotomy is made at an appropriate location, usually at the dome. The ureteroneocystotomy anastomosis is then completed with absorbable suture.

In our modification, the ureter is left in situ and a longitudinal ureterotomy is made just proximal to the level of the stricture. This practice ensures maximal blood supply preservation, theoretically decreasing the likelihood of failure. Additionally, avoiding circumferential dissection of the ureter decreases operating time and reduces the risk of injury to the posteriorly located iliac vessels.[12] Lastly, with this approach the native ureteral orifice is maintained, facilitating easy access to the ureter for possible future endoscopic intervention (eg, urolithiasis). The space of Retzius is then developed and the bladder is dropped onto the ureter. The bladder is insufflated with air to avoid fluid extravasation upon making a cystotomy. A cystotomy at a location matching the ureterotomy is made. The anastomosis is completed using 3-0 absorbable barbed suture. Before completion of the anastomosis, a ureteral stent is advanced in retrograde fashion. It is important to ensure adequate mobilization of the bladder to achieve a tension-free anastomosis. If there is any concern regarding this, then the bladder should be thoroughly freed from its anterior attachments. In a retrospective study comparing 10 robotic reimplantations with 24 open repairs, Kozinn and associates[13] found both approaches have durable outcomes, with no recurrence of stricture disease at over 2 years of follow-up.

Psoas Hitch

The psoas hitch is an essential maneuver in the management of distal ureteral stricture. Laparoscopic psoas hitch and Boari flap were first described in 2001.[14,15] The psoas tendon is exposed and an absorbable suture is used to fix the bladder to the psoas tendon to relieve tension at the anastomosis. The suture should be passed longitudinally along the psoas tendon to avoid the genitofemoral nerve. Alternatively, the bladder can be fixed to the side wall peritoneum to similar effect. As in the nontransecting reimplantation described above, the ureter can be left in situ and reimplantation performed in a nontransecting manner.

In the largest prospective series of robotic psoas hitch, all 12 patients who underwent treatment with distal ureteral reimplantation with psoas hitch had successful outcomes with no obstruction on postoperative MAG-3 scan or IV urography.[16]

Boari Flap

When psoas hitch provides inadequate bladder reach to the ureterotomy, a Boari flap is the next adjunctive maneuver that can be used to provide 3 to 15 cm of mobility with success rates reported from 95% to 100%.[17] With the space of Retzius fully developed, a pedicle of bladder is dissected from the anterior bladder wall. The apex is approximately 3 cm proximal to the bladder neck, and the incision is extended toward the dome to create a trapezoidal flap of tissue with the pedicle base wider than the apex. The flap is fixed to the psoas, tubularized, and anastomosed to the ureter.[13,18] In the largest series of robotic ureteral reimplantation with a Boari flap, all 11 patients had durable repair of their distal stricture at 15 months of follow-up.[19]

Distal Ureteroureterostomy

In this technique, the ureter is circumferentially mobilized and the diseased ureter excised. The remaining healthy ends of the ureter are spatulated 1 to 2 cm and reanastomosed using absorbable suture to approximate the mucosal edges. Particular care is taken to avoid manipulation of the tissue or application of monopolar cautery to preserve the periureteric blood supply. As in the previously described repairs, a stent is exchanged over the guidewire after completion of the posterior anastomosis. Traditionally, UU is used for mid and proximal stricture (discussed elsewhere in this article) owing to concern for higher failure rates associated with the tenuous vasculature of the distal ureter. However, there are small series reporting success with this approach distally.[20] Unlike ureteral reimplantation or a Boari flap, this approach preserves the natural integrity of the bladder and ureteral antireflux mechanism. The risk of disruption of blood supply from circumferential ureteral dissection must be balanced with the benefits of this technique. It is best suited to relatively short (<3 cm), unifocal stenosis in nonirradiated fields. Paick and colleagues[21] reported successful open UU in 9 patients. This technique was adapted to the robot by Lee and colleagues[4,22] who reported the first robotic assisted UU in 2010, and expanded on their case series in 2013. Of the 12 patients in the series, only 1 stricture recurred at medium-term follow-up. The largest published series reports successful distal UU in 21 patients.[23]

Middle and Proximal Ureteral Reconstruction

Ureteroureterostomy

UU has traditionally been performed for short strictures (<3 cm) proximal to the crossing of the iliac vessels.[24,25] The stricture is excised and the ureteral ends are mobilized until a tension free anastomosis is possible. Opposite sides of the proximal and distal ureteral ends are spatulated and the anastomosis is completed with absorbable suture over a ureteral stent. It is prudent to re-retroperitonealize the repair to decrease the risk of fistulization. Lee and colleagues advocate for concomitant downward nephropexy in which the proximal ureter and kidney are fully dissected and mobilized caudad. In doing so they estimate 3 to 4 cm of mobilization is possible.

Appendiceal flap

The appendiceal flap ureteroplasty has many advantages, including relative ease of appendiceal mobilization, defined blood supply, negligible absorption of urine over the small surface area, ability to replace totally obliterated ureteral segments, and lack of donor site morbidity compared with a buccal mucosa graft (BMG) ureteroplasty. For this reason, it should be considered when the appendiceal anatomy is favorable. The technique was first described in 1912 by Melnikoff[26] using end-to-end anastomosis, but use was infrequently reported until recently.[27,28] In 2009, Reggio and colleagues[29] reported a successful laparoscopic appendiceal onlay flap ureteroplasty of a nonobliterative right ureteral stricture. Through the use of the onlay technique, not only is the ureteral blood supply minimally disrupted, but the appendiceal flap carries with it its own blood supply and may theoretically be a superior option in cases of impaired vascularity, such as radiation-induced strictures.

Port placement is similar to the previously described setup. Of note, a 12-mm port will need to be placed to accommodate a laparoscopic stapler, which will be used to harvest the appendiceal flap. Once harvested, the 2 ends of the appendix are opened and the lumen is cleared with suction and irrigation. The appendix is opened longitudinally along its antimesenteric border in the case of onlay. The mesentery of the appendix is carefully mobilized to facilitate a tension-free anastomosis (**Fig. 3**). IV ICG can be useful during this maneuver because it will highlight the main vascular trunk of the mesoappendix, which is to be avoided (**Fig. 4**). A ventral ureterotomy is made and anastomosis is performed similarly to that previously described for buccal grafts. If the appendix is not appropriate for ureteroplasty, the mesentery is divided with the stapler and appendectomy completed.

Outcome data for minimally invasive appendiceal graft techniques are favorable. In 2015, a case series of 6 patients from Reggio and colleagues[30] reported no recurrences at 16 months of follow-up. All strictures were right sided with an average length of 2.5 cm. Case reports have shown that this procedure translates well into

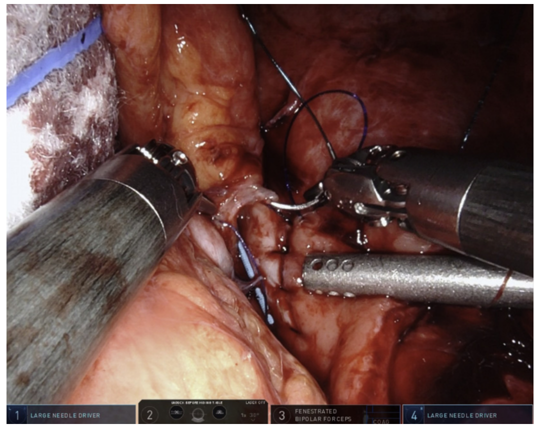

Fig. 3. Proximal right ureteral stricture. The lateral edge anastomosis of an appendiceal onlay is nearing completion. The opened appendiceal flap is seen underneath the suction tip while the needle is seen entering the distal apex of the opened right ureter.

robotic technique, with Yarlagadda and colleagues[31] reporting the use of tubularized appendiceal interposition for a 5 cm obliterative right ureteral stricture with no recurrence at 10 months. More complex repairs are also possible; Gn and colleagues[32] described a panureteral appendiceal ureteroplasty for an iatrogenic avulsion, requiring simultaneous downward nephropexy, psoas hitch, and calycostomy.

Oral mucosa graft onlay

Buccal mucosa graft (BMG) is particularly well-suited for urinary reconstruction owing to a panvascular lamina propria, epithelium adapted to a wet environment, well-tolerated donor site morbidity, and good take even in irradiated and

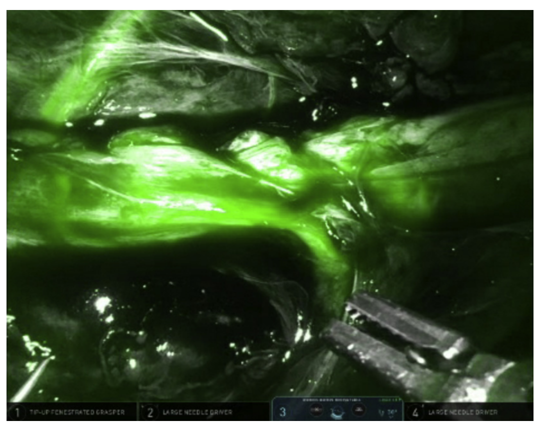

Fig. 4. IV ICG highlights the vascular pedicle of the appendiceal flap with near infrared laparoscopy, confirming viability of the mobilized flap at its new location.

reoperative fields.[33,34] BMG ureteroplasty was first reported by Naude in 1999.[35] Although it has been increasingly prominent in urethroplasty over the past 2 decades, it was not frequently used in ureteroplasty over this period.[36] In 2015, Zhao and colleagues[37] reported their experience with robotic BMG ureteroplasty with a follow-up multi-institutional study. In that study, 19 patients with average stricture length of 4 cm treated with BMG ureteroplasty showed 90% success at a median follow-up of 26 months.

After initial robotic access and exposure of the ureter is obtained, an anterior ureterotomy is extended the length of the stricture. We prefer a ventral onlay because this allows one to preserve the posterior blood supply and avoid circumferential dissection, as mentioned elsewhere in this article. In cases of short obliterative strictures, the obliterated section is excised and the ventral portion of the 2 ureteral ends are spatulated. A posterior ureteral plate is established through the anastomosis of the dorsal ureteral ends with absorbable barbed suture (**Fig. 5**). IV ICG may be used to confirm adequate blood supply to the ureter. Once adequate blood supply is confirmed, stay sutures are placed to mark the apices. The stricture length is measured to determine the necessary graft size and the BMG harvest is performed. If adjunctive maneuvers, such as downward nephropexy, do not result in a tension-free anastomosis, one should consider an ileal ureter.

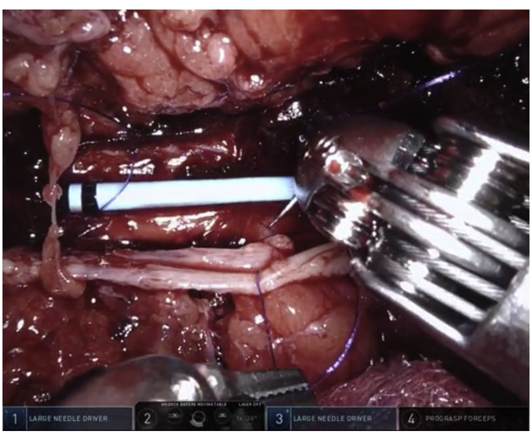

Fig. 5. An 11-cm left ureteral stricture, which included a 3-cm segment of complete obliteration owing to a cryoablation injury for a lower pole renal mass. An augmented anastomotic ventral onlay buccal mucosal graft ureteroplasty with downward nephropexy was performed. The posterior wall has been reestablished in an interrupted fashion. Seen in the picture is the anastomosis of the medial edge of an 8 cm buccal graft.

A mouth retractor with a tongue blade is positioned and 2 to 3 holding sutures are placed on the lip for retraction. A headlamp is useful for visualization. Stenson's duct is identified and marked. Lidocaine (1%) with 1:100,000 epinephrine is used for hydrodissection and to minimize bleeding. A buccal graft 1 cm wide by the length of the ureteral stricture is harvested. The graft is defatted and passed to the robotic surgeon with a suture to facilitate graft handling. The buccal defect can be left open or closed at the surgeon's preference. The BMG is oriented over the ureterotomy with mucosal surface facing the ureteral lumen, and the edges are anastomosed with barbed absorbable suture. A flap of omentum or perinephric fat is then fixed over the graft to provide a vascular source on which to take.

Retrocaval ureter

Retrocaval ureter is a congenital abnormality in which the right ureter runs posterior to the inferior vena cava. A few options for patients with symptomatic ureteral obstruction are reported. Traditionally, these choices have been UU or pyelopyelostomy. Robotic-assisted UU for retrocaval ureter was first described in 2006 in the pediatric population and further developed in 2011 by LeRoy and colleagues.[38,39] In the latter approach, the normal ureter is transected leaving the retrocaval segment of the ureter in situ. The normal ureter is then transposed anterior to the vena cava and a UU is performed, taking care to minimize distal ureteral dissection to avoid stricture recurrence.[40] Although there is a theoretic risk that the retained retrocaval ureter may undergo malignant transformation, the rarity of this condition precludes any evidence-based conclusion. Simforoosh and colleagues[41] reported 6 cases in which the retrocaval ureter was left in situ without complication.

Ileal ureter

Ileal ureteral substitution is an important fallback technique, and all patients should be counseled on the possibility of requiring one if the previously mentioned approaches are insufficient. Ileal ureter may be contraindicated in patients with inflammatory bowel disease, bladder outlet obstruction, neurogenic bladder, and short gut.[42] Potential complications include bowel obstruction, fistula, bowel leak, and long-term metabolic complications, including metabolic acidosis, vitamin B_{12} malabsorption, and increased risk of nephrolithiasis and cholelithiasis owing to bile acid malabsorption.[43]

The first ileal ureter was described in 1959[44] and further refined in the 1990s by Yang and Monti and colleagues for longer strictures.[45,46] Robotic ileal ureter was first described in 2008 by Wagner and colleagues[47] and has since been modified further to be performed entirely intracorporeally.[48] In 2016, Chopra and colleagues[49] reported a 3-case series of robotic ileal ureter in which 1 patient suffered a volvulus resulting in loss of ileal ureter on postoperative day 4. The remaining 2 cases were successful. Most recently, Ubrig and colleagues[50] reported a 7-patient series of robotic intracorporeal ileal ureter of which 5 patients underwent simultaneous psoas hitch. The mean length of transposed ileum was 20.4 cm. All patients were symptom free at the 3-month follow-up.[50]

After the ureter is isolated and the patent ends of the ureter exposed (or bladder and renal pelvis), an appropriate length of ileum 20 cm proximal to the ileocecal valve is harvested with a laparoscopic stapler. Bowel continuity is restored in standard fashion. Proximally, the bowel may be anastomosed to the ureter, renal pelvis, or lower pole calyx, depending on stricture severity. One must ensure adequate spatulation to accommodate anastomosis to the end of the bowel. Alternatively, a side-to-side anastomosis may be more appropriate; this should be judged on a case-by-case basis. Distally, the end of the ureter is anastomosed to the bladder or spatulated distal ureteral stump. For bilateral ureteral stricture, a longer segment of ileum may be harvested and the ureteral anastomoses performed on both ends. The most dependent portion of the bowel segment is allowed to lay on the bladder in a U configuration. An approximately 5-cm enterotomy is made on the antimesenteric side, and a matching cystotomy is made at the dome of the bladder. An anastomosis between the two is completed with absorbable barbed suture. IV ICG is useful to confirm adequate perfusion at the level of the anastomoses. A ureteral stent is placed in usual fashion over a wire before complete closure. The bladder is irrigated to confirm a water-tight anastomosis.

Autotransplantation

Robotic-assisted kidney autotransplantation is reserved as a salvage procedure. It was first described in 1962 by Hardy[51] as an open procedure. In 2000, Fabrizio and colleagues[52] reported the first laparoscopic renal autotransplant, which consisted of a laparoscopic donor nephrectomy, extraction of the kidney through a midline incision, and standard transplantation through a Gibson incision. Completely intracorporeal robotic-assisted kidney autotransplantation was first reported in 2014 and has since been replicated at several institutions.[53–56] It remains a technically demanding but feasible procedure when all other options have been exhausted.

POSTOPERATIVE MANAGEMENT

Distal Reconstruction

If a drain is placed intraoperatively, it will be removed before discharge unless output is high. Because a cystotomy has been performed, patients are discharged from the hospital with a Foley catheter. A cystogram is performed at 1 to 2 weeks postoperatively, and the Foley is removed if there is no evidence of leak. The stent is removed at the 4-week postoperative visit.

Proximal and Mid Reconstruction

The Foley catheter is removed on postoperative day 1. The drain is removed after Foley removal the same day if output remains low. The stent is removed in the clinic 4 weeks later.

Ileal Ureter

If an ileovesical anastomosis was performed, a cystogram is obtained 2 weeks postoperatively, and the Foley catheter is removed if there is no evidence of leakage. The ureteral stent is removed 4 weeks postoperatively.

Postoperative Imaging

Although we have not found retrograde pyelogram necessary at the time of stent removal, this is an option based on practice preference We obtain a renal ultrasound examination 6 to 12 weeks after stent removal followed by a diuretic renal scan at 6 months. If ultrasound findings or patient symptoms are concerning for ureteral obstruction, the renogram may be obtained sooner.

Nephrostomy Management

A nephrostomy tube is kept or removed at the end of surgery on a case-by-case basis. For example, if the patient has a history of recurrent obstruction and sepsis, it may be prudent to keep the nephrostomy, which will remain through stent removal. The patient will then be instructed to place the nephrostomy to drainage if renal colic or pyelonephritis ensues. The nephrostomy tube is generally removed 1 week after stent removal if the patient remains symptom free.

MANAGEMENT

We use an algorithmic approach for the treatment of ureteral stricture. For distal ureteral strictures, we prefer a nontransecting ureteral reimplantation, performing a psoas hitch and then a Boari flap as

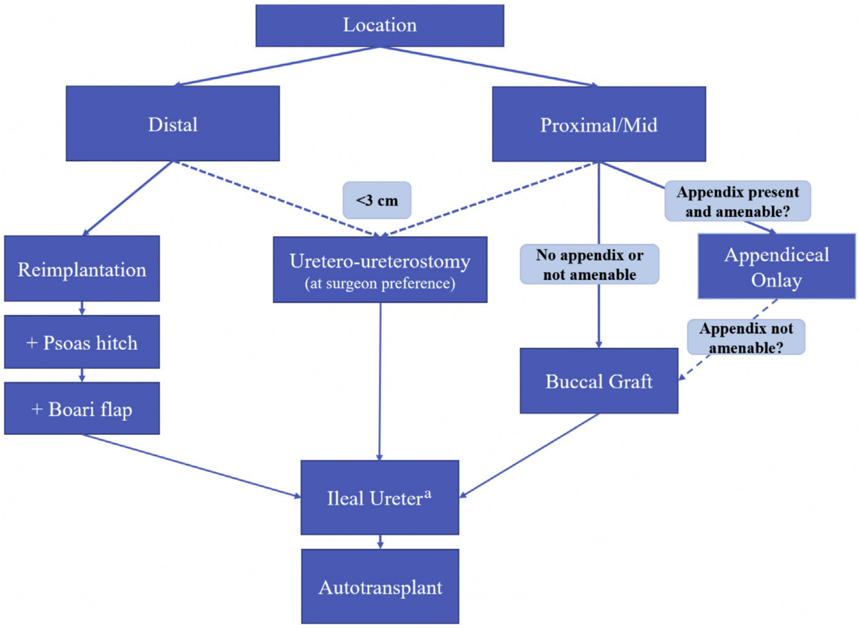

Fig. 6. Treatment decision tree. [a]Consider if prior radiation or multiple surgeries.

needed for added length. For middle to proximal right-sided ureteral strictures, if the appendix is available, we prefer to use it as a ventral onlay. For obliterated lumens, we prefer an augmented anastomotic approach. If one cannot perform an appendiceal flap reconstruction, we will perform buccal graft ureteroplasty. If a buccal graft is impractical, we will perform ileal ureteral substitution. The need for autotransplantation is rare and reserved for salvage cases. For multifocal unilateral or bilateral strictures, one may combine techniques. For example, one may perform a nontransecting ureteral reimplantation and a ventral buccal onlay at the same time (Fig. 6).

SUMMARY

The last 2 decades have seen the rapid adaption of time-tested techniques of ureteroplasty to the robotic-assisted laparoscopic approach. With that, morbidity continues to improve as techniques become less invasive. This article has sought to describe those techniques with an algorithm to guide their application. Although more advancements will undoubtedly be made, it is important to adhere to fundamental reconstructive principles and to have a contingency procedure, such as ileal ureteral substitution, should the need arise. Ureteral stricture management with serial ureteral stent exchanges is an all too common history encountered in reconstructive urology. The current armamentarium of ureteroplasty techniques now provides a safe, effective, and tolerable means of surgical cure.

CLINICS CARE POINTS

- One should strive to minimally disrupt the ureteral blood supply by avoiding circumferential dissection and transection. Onlay is preferred to interposition.
- An algorithmic approach ensures that the most effective and least invasive method of ureteral reconstruction is undertaken.
- The surgeon should be prepared at the time of surgery to perform an ileal ureter in the event if less invasive techniques are not feasible.

DISCLOSURE

L.C. Zhao is a consultant for Intuitive Surgical. M.S. Jun and A. Drain do not have any conflicts of interest to declare.

REFERENCES

1. Babbar P, Yerram N, Sun A, et al. Robot-assisted ureteral reconstruction – current status and future direction. Urol Ann 2018;10:7–14.
2. Nezhat C, Nezhat F, Green B. Laparoscopic treatment of obstructed ureter due to endometriosis by resection and ureteroureterostomy: a case report. J Urol 1992;148:865–8.

3. Yohannes P, Chiou RK, Pelinkovic D. Rapid communication: pure robot-assisted laparoscopic ureteral reimplantation for ureteral stricture disease: a case report. J Endourol 2003;17(10):891–3.
4. Lee Z, Llukani E, Reilly CE, et al. Single surgeon experience with robot-assisted ureteroureterostomy for pathologies at the proximal, middle, and distal ureter in adults. J Endourol 2013;27:994–9.
5. Tracey AT, Eun DD, Stifelman MD, et al. Robotic-assisted laparoscopic repair of ureteral injury: an evidence-based review of techniques and outcomes. Minerva Urol Nefrol 2018;70(3):231–41.
6. Lee Z, Moore B, Giusto L, et al. Use of indocyanine green during robot-assisted ureteral reconstructions. Eur Urol 2015;67:291–8.
7. Arora S, Campbell L, Tourojman M, et al. Robotic buccal mucosal Graft ureteroplasty for complex ureteral stricture. Urology 2017;110:257–8.
8. Casale P, Patel RP, Kolon TF. Nerve sparing robotic extravesical ureteral reimplantation. J Urol 2008; 179:1987–90.
9. Terlecki RP, Steele MC, Valadez C, et al. Urethral rest: role and rationale in preparation for anterior urethroplasty. Urology 2011;77:1477–81.
10. Bjurlin MA, Gan M, McClintock TR, et al. Near-infrared fluorescence imaging: emerging applications in robotic upper urinary tract surgery. Eur Urol 2014;65:793–801.
11. van Manen L, Handgraaf HJM, Diana M, et al. A practical guide for the use of indocyanine green and methylene blue in fluorescence-guided abdominal surgery. J Surg Oncol 2018;118(2):283–300.
12. Slawin J, Patel NH, Lee Z, et al. Ureteral Reimplantation via Robotic Nontransecting Side-to-Side Anastomosis for Distal Ureteral Stricture. J Endourol 2020 Aug;34(8):836–9. https://doi.org/10.1089/end.2019.0877. Epub 2020 May 5. PMID: 32233674.
13. Kozinn SI, Canes D, Sorcini A, et al. Robotic versus open distal ureteral reconstruction and reimplantation for benign stricture disease. J Endourol 2012; 26(2):147–51.
14. Ahn M, Loughlin KR. Psoas hitch ureteral reimplantation in adults—analysis of a modified technique and timing of repair. Urology 2001;58:184–7.
15. Fugita OE, Dinlenc C, Kavoussi L. The laparoscopic Boari flap. Urology 2001;166(1):51–3.
16. Patil NN, Mottrie A, Sundaram B, et al. Robotic-assisted laparoscopic ureteral reimplantation with psoas hitch: a multi-institutional, multinational evaluation. Urology 2008;72(1):47–50.
17. Nakada SY, Best SL. Management of upper urinary tract obstruction. In: Wein AJ, Kavoussi LR, Partin AW, et al, editors. Campbell-Walsh urology. 11th edition. Philadelphia: Elsevier; 2016. p. 1135.
18. Schimpf MO, Wagner JR. Robot-assisted laparoscopic Boari flap ureteral reimplantation. J Endourol 2008;22(12):2691–4.
19. Stolzenburg JU, Rai BP, Do M, et al. Robot-assisted technique for Boari flap ureteric reimplantation: replicating the techniques of open surgery in robotics. BJU Int 2016;118:482–4.
20. Asghar AM, Lee RA, Yang KK, et al. Robot-assisted distal ureteral reconstruction for benign pathology: current state. Investig Clin Urol 2020;61(Suppl 1): S23–32.
21. Paick JS, Hong SK, Park MS, et al. Management of postoperatively detected iatrogenic lower ureteral injury: should ureteroureterostomy really be abandoned? Urology 2006;67(2):237–41.
22. Lee DI, Schwab CW, Harris A. Robot-assisted ureteroureterostomy in the adult: initial clinical series. Urology 2010;75:570–3.
23. Buffi NM, Lughezzani G, Hurle R, et al. Robot-assisted surgery for benign ureteral strictures: experience and outcomes from four tertiary care institutions. Eur Urol 2017;71:945–51.
24. Andrade HS, Kaouk JH, Zargar H, et al. Robotic ureteroureterostomy for treatment of a proximal ureteric stricture. Int Braz J Urol 2016;42:1041–2.
25. Raheem AA, Alatawi A, Kim DK, et al. Feasibility of robot-assisted segmental ureterectomy and ureteroureterostomy in patient with high medical comorbidity. Int Braz J Urol 2017;43:779–80.
26. Melnikoff AE. Sur le replacement de l'uretere par anse isolee de l'intestine grele. Rev Clin Urol 1912;1:601–3.
27. Richter F, Stock JA, Hanna MK. The appendix as right ureteral substitute in children. J Urol 2000; 163:1908–12.
28. Juma S, Nickel JC. Appendix interposition of the ureter. J Urol 1990;144:130–1.
29. Reggio E, Richstone L, Okeke Z, et al. Laparoscopic ureteroplasty using on-lay appendix graft. Urology 2009;73(4):928.
30. Duty BD, Kreshover JE, Richstone L, et al. Review of appendiceal onlay flap in the management of complex ureteric strictures in six patients: appendiceal onlay flap in management of ureteric strictures. BJU Int 2015;115:282–7.
31. Yarlagadda VK, Nix JW, Benson DG, et al. Feasibility of intracorporeal robotic-assisted laparoscopic appendiceal interposition for ureteral stricture disease: a case report. Urology 2017;109:201–5.
32. Gn M, Lee Z, Strauss D, et al. Robotic appendiceal interposition with right lower pole calycostomy, downward nephropexy, and psoas hitch for the management of an iatrogenic near-complete ureteral avulsion. Urology 2018;113:e9–10.
33. Somerville JJ, Naude JH. Segmental ureteric replacement: an animal study using a free non-pedicled graft. Urol Res 1984;12(2):115–9.
34. Naude JH. Buccal mucosal grafts in the treatment of ureteric lesions. BJU Int 2001;83:751–4.
35. Naude JH. Buccal mucosal grafts in the treatment of ureteric lesions. BJU Int 1999;83(7):751–4.

36. Wessells H, Angermeier KW, Elliott S, et al. Male urethral stricture: American Urological Association guideline. J Urol 2017;197:182–90.
37. Zhao LC, Yamaguchi Y, Bryk DJ, et al. Robot-assisted ureteral reconstruction using buccal mucosa. Urology 2015;86:634–8.
38. Gundeti MS, Duffy PG, Mushtaq I. Robotic-assisted laparoscopic correction of pediatric retrocaval ureter. J Laparoendosc Adv Surg Tech 2006;16:422–4.
39. LeRoy TJ, Thiel DD, Igel TC. Robot-assisted laparoscopic reconstruction of retrocaval ureter: description and video of technique. J Laparoendosc Adv Surg Tech 2011;21(4):349–51.
40. Liu E, Sun X, Guo H, et al. Retroperitoneoscopic ureteroplasty for retrocaval ureter: report of nine cases and literature review. Scand J Urol 2016;50:319–22.
41. Simforoosh N, Nouri-Mahdavi K, Tabibi A. Laparoscopic pyelopyelostomy for retrocaval ureter without excision of the retrocaval segment: first report of 6 cases. J Urol 2006;175:2166–9.
42. Mattos RM, Smith JJ 3rd. Ileal Ureter. Urol Clin North Am 1997;24(4):813–25.
43. Martini A, Villari D, Nicita G. Long-term complications arising from bowel interposition in the urinary tract. Int J Surg 2017;44:278–80.
44. Goodwin WF, Winter CC, Turner RD. Replacement of the ureter by small intestine: clinical application and results of the 'ileal ureter'. J Urol 1959;81:406–18.
45. Yang H. Yang needle tunneling technique in creating anti-reflux and continent mechanisms. J Urol 1993; 150:830–46.
46. Monti PR, Lara RC, Dutra MA, et al. New techniques for construction of efferent conduits based on the Mitrofanoff principle. Urology 1997;49:112–5.
47. Wagner JR, Schimpf MO, Cohen JL. Robot-assisted laparoscopic ileal ureter. JSLS 2008;12(3):306–9.
48. Brandao LF, Autorino R, Zargar H, et al. Robotic ileal ureter: a completely intracorporeal technique. Urology 2014;83:951–4.
49. Chopra S, Metcalfe C, Satkunasivam R, et al. Initial series of four-arm robotic completely intracorporeal ileal ureter. J Endourol 2016;30:395–9.
50. Ubrig B, Janusonis J, Paulics L, et al. Functional outcomes of completely intracorporeal robotic ileal ureteric replacement. Urology 2018;114:193–7.
51. Hardy JD. High ureteral injuries. Management by autotransplantation of the kidney. JAMA 1963;184: 97–101.
52. Fabrizio MD, Kavoussi LR, Jackman S, et al. Laparoscopic nephrectomy for autotransplantation. Urology 2000;55:145.
53. Gordon ZN, Angell J, Abaza R. Completely intracorporal robotic renal autotransplantation. J Urol 2014; 192:1516–22.
54. Lee JY, Alzahrani T, Ordon M. Intra-corporeal robotic renal autotransplantation. Can Urol Assoc J 2015;9: E748–9.
55. Decaestecker K, Van Parys B, Van Besien J, et al. Robot-assisted kidney autotransplantation: a minimally invasive way to salvage kidneys. Eur Urol Focus 2018;4(2):198–205.
56. Doumerc N, Beauval JB, Roumiguie M, et al. Total intracorporeal robotic auto-transplantation: a new minimally invasive approach to preserve the kidney after major ureteral injuries. Int J Surg Case Rep 2018;49:176–9.