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Review

A review of complications after ureteral reconstruction

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Abstract *Objective:* This study aimed to provide a comprehensive overview of the complications unique to ureteral reconstruction in adults, emphasizing their presentation, diagnosis, and management in the treatment of ureteral structure disease.
Methods: This review involves an in-depth analysis of existing literature and case studies pertaining to ureteral reconstruction, with a focus on examining the range of complications that can arise post-surgery. Special attention is given to the presentation of each complication, the diagnostic process involved, and the subsequent management strategies.
Results: Ureteral reconstruction can treat ureteral stricture disease with low morbidity; however, complications, although uncommon, can have severe consequences. The most notable complications include urinary extravasation, stricture recurrence, urinary tract infections, compartment syndrome, symptomatic vesicoureteral reflux, and Boari flap necrosis. Each complication presents unique diagnostic challenges and requires specific management approaches.
Conclusion: Ureteral reconstruction is a highly effective treatment for ureteral stricture disease. Having a strong understanding of the potential complications that patients may experience following ureteral reconstruction is not only critical to adequately counsel patients but also facilitate prompt diagnosis and management of complications when they arise.

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1. Introduction

Ureteral reconstruction, the definitive treatment for ureteral stricture disease, is generally associated with excellent long-term ureteral patency rates and low morbidity [1—3]. Although complications after ureteral reconstruction are uncommon, they may lead to devastating consequences. Traditionally, ureteral reconstruction has been performed via an open incision, which may be technically difficult given the need for visualization in the deep retroperitoneum, and intricate suturing. Additionally, there may be significant postoperative pain and delay to return to normal activity associated with a large open incision. To decrease morbidity after ureteral reconstruction, there has been an increasing emphasis on minimally invasive techniques [3].

Nezhat et al. [4] reported the first case of laparoscopic ureteral reconstruction in 1992, in which the authors described ureteroureterostomy. Laparoscopic ureteral reconstruction, when compared to open ureteral reconstruction, has been shown to be associated with decreased postoperative pain, length of hospital stay, and postoperative complications while maintaining similar success rates [5,6]. Despite this, widespread adoption of laparoscopic ureteral reconstruction has been limited given the technical difficulty of dissecting without wristed instrumentation, operating using two-dimensional visualization, and intracorporal suturing [1, 7]. Yohannes et al. [8] reported the first case of robotic ureteral reconstruction in 2003 in which the authors described robotic ureteral reimplantation utilizing the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). The robotic modality maintains the benefits of minimally invasive surgery such as improved cosmesis, decreased hospital stay, and reduced postoperative pain; and additionally provides surgeons with benefits such as three-dimensional magnified visualization, wristed instrumentation, and integration of near-infrared fluorescence. These attributes have allowed for widespread adoption of robotic ureteral reconstruction. Sukumar et al. [3] found that by 2009, the robotic platform was the most common modality to perform pyeloplasty. Although robotic ureteral reconstruction is associated with high safety and success rates, complications still occur [9]. In a 2017 multi-center study, Buffi et al. [2] found an overall complication rate of 11% and a major complication rate of 2.2% after robotic ureteral reconstruction, including pyeloplasty and ureteroureterostomy.

Understanding the complications that patients may face following ureteral reconstruction not only allows for proper preoperative surgical counseling, but also helps identify opportunities for improvement in patient outcomes. Herein, we perform a narrative review of complications unique to ureteral reconstruction in adults, and discuss their presentation, diagnosis, and management. Given the widespread use of the robotic modality in contemporary ureteral reconstruction, we focus our discussion on complications after robotic ureteral reconstruction. Given the paucity of literature dedicated to complications of ureteral reconstruction and the lack of guidelines to direct their management, we supplement our review of the literature with commentaries based on our experience at a high-volume robotic ureteral reconstruction center.

2. General complications after ureteral reconstruction

2.1. Urinary extravasation

Urinary extravasation after ureteral reconstruction generally occurs at the anastomotic suture line. The reported incidences of urinary extravasation after ureteral reconstruction are 1.8%—8.8% after pyeloplasty [10,11], 1.3% after ureteroureterostomy [12], and 0.6%—4.1% after reimplantation [12,13]. Although urinary extravasation after ureteral reconstruction is relatively uncommon, this complication may result in devastating consequences for patients such as sepsis, need for secondary procedures, and stricture recurrences [10,11,14,15]. In a multi-institutional study by Sivaraman et al. [11] that evaluated outcomes after robotic pyeloplasty, 3/168 (1.8%) of patients were diagnosed with urinary leaks and they all required laser endopyelotomy for anastomotic stricture recurrence.

Patients with urinary extravasation after ureteral reconstruction may present with fever, flank and/or pelvic pain, low urine output, and increased drainage output in a surgical drain (if one was utilized). When a patient has symptoms suggestive of urinary extravasation, the diagnosis may generally be made via cross-sectional imaging in the form of a CT urogram, which may demonstrate extravasation of contrast or urinoma around the site of reconstruction [10,11,14,15]. When more detailed information regarding the specific site of urinary extravasation is necessary, such as in complex reconstructions or when multiple sites of ureter are reconstructed, intraoperative evaluation with a retrograde pyelogram and/or cystogram (if the bladder was utilized during reconstruction) may be performed (Fig. 1). In patients with a postoperative surgical drain, a two-fold increase in drainage creatinine level compared to serum level is highly suggestive of urinary

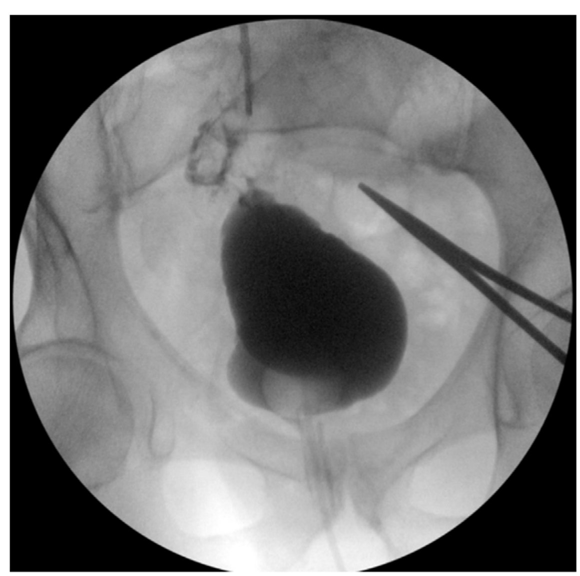

Figure 1 Postoperative urinary extravasation noted on postoperative cystogram secondary to Boari flap necrosis.

extravasation [16—18]. In some cases, urinary extravasation may be asymptomatic and detected on routine postoperative imaging. In patients who underwent ureteral reconstruction utilizing the bladder, a cystogram may detect urinary extravasation at the time of Foley catheter removal [19]. Some authors have utilized postoperative retrograde pyelograms at the time of stent removal after particularly difficult ureteral reconstructions to assess for urinary leaks and confirm patency [20].

Prompt treatment of urinary extravasation, which is necessary to prevent severe complications such as sepsis and abscess formation, generally involves maximizing urinary drainage in order to divert urine away from the disrupted anastomosis. As patients undergoing ureteral reconstruction generally have a stent placed at time of repair, insertion of a Foley catheter may improve urinary drainage [21]. In patients with persistent leakage despite Foley catheterization, placement of a nephrostomy tube may further improve urinary drainage [22]. Additionally, in patients with a large degree of urinary extravasation and/or abscess formation, placement of an interventional radiology drain may be warranted. As patients may have differences in history (*i.e.*, history of radiation and diabetes) and severity of extravasation (*i.e.*, small versus large leak) that may influence time to resolution of urinary extravasation, there are no guidelines to direct duration of additional drains. In our practice, we generally place additional drains in a stepwise progression from least invasive to more invasive (*i.e.*, Foley catheter, then nephrostomy tube, and then interventional radiology drain) and reassess for resolution of urinary extravasation every 2 weeks. Although all urinary leaks generally resolve with urinary drainage and time, it is critical to perform close surveillance in patients with a history of urinary extravasation given the higher risk for stricture recurrence [15]. Rarely, surgical reconstruction may be necessary to manage urinary extravasation.

2.2. Stricture recurrence

Stricture recurrence refers to narrowing of the reconstructed ureter after ureteral reconstruction. After pyeloplasty, the reported stricture recurrence rates range from 2.4% to 19.0% [10,11,23]; after ureteroureterostomy, the reported stricture recurrence rates range from 4.5% to 8.3% [12,24]; and after ureteral reimplantation, the reported stricture recurrence rates range from 2.3% to 11% [12,25]. The current body of literature suggests that surgical modality does not affect stricture recurrence. Rasool et al. [26] compared outcomes after open, laparoscopic, and robotic-assisted approaches for pyeloplasty in 102 patients (each cohort contained 34 patients), and found that there were similar success rates and efficacy irrespective of the technique utilized. Wang et al. [15] retrospectively compared patients with recurrent ureteral strictures after previously failed ureteral reconstruction who underwent robotic versus open approaches for pyeloplasty and ureteroureterostomy at a single institution. The authors found no significance differences in the success rates between patients undergoing robotic (86%) and open (82%) repairs. Robotic surgery, however, was associated with shorter operative times, lower estimated blood loss, and higher costs. In a systematic review comparing stricture recurrence after robotic and open ureteral reimplantation, Kolontarev et al. [27] found that there was no difference in stricture recurrence between robotic (8.9%) and open (9.1%) repairs.

A major challenge in evaluating the literature regarding stricture recurrence after ureteral reconstruction is the lack of a standard definition for surgical success, which has been defined as improvement in renal function [28], improvement of hydronephrosis on surveillance imaging [29], resolution of subjective symptoms, and absence of repeat procedures [30]. Developing a widely agreed-upon definition of surgical success after ureteral reconstruction is critical to not only allow for critical analysis of outcomes following ureteral reconstruction but also standardize care across institutions. We utilize the definition of surgical success proposed by the Collaborative of Reconstructive Robotic Ureteral Surgery (CORRUS) group: the absence of obstructive flank pain and/or ureteral obstruction on radiographic imaging (*i.e.*, retrograde pyelography, CT urography, and/or renal scan) [22,30,31].

Patients with stricture recurrence may present with flank pain and decreased renal function. However, a significant proportion of patients with stricture recurrence will be asymptomatic. In a study evaluating 41 patients with stricture recurrence after ureteral reconstruction, Wang et al. [15] noted that the most common presenting symptoms of stricture recurrence were flank pain (56%) and fever (7.3%). Thirty-four percent of patients with stricture recurrence were asymptomatic [15]. These data underscore the importance of surveillance in patients who underwent ureteral reconstruction, given the negative implications of stricture recurrence on renal function.

There is currently no standardized method to diagnose stricture recurrence. Furthermore, there are no guidelines regarding surveillance protocols to direct the follow-up after ureteral reconstruction. Renal ultrasound, CT, radionucleotide renal scans, and intraoperative evaluation may be utilized to diagnose stricture recurrence [30]. We prefer to utilize mercaptoacetyltriglycine-3 renal scans to screen patients for stricture recurrence, and generally consider patients with $t_{1/2}$ greater than 15 min to be suspicious for stricture recurrence. In asymptomatic patients, we generally screen patients for stricture recurrence postoperatively at 3 months, 6 months, 12 months, and yearly thereafter. We strongly recommend continuing to surveil patients chronically after ureteral reconstruction because although most recurrences occur within the first 2 years following surgery, 30% of recurrences may occur after 2 years [3,23]. In patients with a suspicion for stricture recurrence on renal scan, we perform ureteroscopy to visually assess for the presence of a patent ureter; if an 8 French ureteroscope is unable to pass across the reconstructed site, we consider this to be a stricture recurrence (Fig. 2).

Identifying risk factors for stricture recurrence is important as this may alter surveillance protocols. In a systematic review evaluating risk factors associated with pyeloplasty failure, Chow et al. [28] found that split renal function of less than 30%, history of a prior endopyelotomy,

Figure 2 Endoscopic visualization of stricture recurrence via ureteroscopy after pyeloplasty.

and early urine leak were associated with the higher risk for stricture recurrence. Currently, there is limited literature evaluating risk factors for stricture recurrence after ureteral reimplantation.

When a patient develops stricture recurrence after ureteral reconstruction, it is critical to assess remaining renal function in the affected kidney, as this may affect treatment decisions. Typically, patients with split renal function of less than 20% in a kidney with a ureteral stricture recurrence are not offered renal salvage [32,33]. However, there has been a growing body of literature suggesting that ureteral reconstruction in patients with less than 20% split renal function may result in renal function preservation without deterioration [32,34]. In our practice, we generally do not perform ureteral reconstruction when split renal function in the affected kidney is less than 15% in the setting of normal global renal function.

In patients with ureteral stricture recurrence in the setting of a salvageable kidney, several options for management exist. Chronic nephroureteral stent or nephrostomy tube may be utilized for long-term urinary drainage. While this option allows the patient to avoid a major surgical reconstruction, these options may lead to pain relating to hardware, irritative voiding symptoms (in the case of a nephroureteral stent), urinary tract infections (UTIs), and need for regular hardware exchanges [35]. We typically reserve this treatment option for patients with poor baseline functional status who are at high operative risks.

Endoscopic management via ureteral dilation and/or endopyelotomy is often utilized as the first-line treatment in the setting of recurrent ureteral stricture disease. Although these options all allow the patient to avoid a major surgical reconstruction, long-term success rates for these procedures are generally considered to be limited. In patients with a history of prior ureteral reconstruction, studies have shown that endopyelotomy is associated with success rates of 39.0%−70.0% [36,37] and balloon dilation is associated with a 20.0% success rate [38].

Although redo ureteral reconstruction is the most definitive treatment of a recurrent ureteral stricture and is associated with excellent success rates, the procedure may be technically challenging given obliteration of normal dissection planes, fragile ureteral blood supply, and severe peri-ureteral fibrosis [30,31]. The majority of the literature regarding reoperative ureteral reconstruction for recurrent stricture disease focuses on outcomes of secondary pyeloplasty, which has been associated with success rates of 85.7%−90.6% [31,39]. Reports evaluating outcomes of reoperative ureteral reconstruction in locations other than the ureteropelvic junction are limited. Additionally, a significant proportion of the literature evaluating ureteral reconstruction of recurrent strictures combines experiences evaluating recurrent strictures after endoscopic and surgical treatments. In the most robust experience regarding reoperative ureteral reconstruction to date, Lee et al. [30] reported a multi-institutional series in which 105 patients underwent reoperative robotic ureteral reconstruction at the ureteropelvic junction (n=43), and proximal (n=15), middle (n=10), and distal (n=37) ureters. Redo ureteral reconstructions at the ureteropelvic junction, proximal ureters, middle ureters, and distal ureters were associated with 90.7%, 86.7%, 80.0%, and 91.9% success rates, respectively. The investigators utilized a multitude of techniques depending on the level of ureteral stricture disease, including robotic pyeloplasty ureteroureterostomy, ureterocalicostomy, buccal mucosa graft (BMG) ureteroplasty, reimplantation (with psoas hitch and Boari flap) and appendiceal bypass. There was low morbidity associated with the reconstructions, as the median length of stay was 2 days, and the overall major (Clavien−Dindo grade >2) complication rate was 1.9%. However, it must be noted that 50.5% of patients had prior ureteral reconstruction, while 49.5% of patients only underwent prior endoscopic intervention. Although the current body of literature does support the efficacy of reoperative ureteral reconstruction in the setting of prior ureteral reconstruction, further research investigating reoperative ureteral reconstruction after previously failed ureteral reconstruction and not just endoscopic management is necessary. Additionally, further research of ureteral reconstruction beyond the level of the ureteropelvic junction is necessary.

One technique used to treat recurrent ureteral stricture that deserves further discussion is BMG ureteroplasty. The BMG is well-suited for substitution reconstruction in the urinary tract as it is hairless, readily accessible, compatible with a wet environment, and has a highly vascular lamina propria that facilitates graft take. The first report of BMG ureteroplasty was by Naude [40] in 1999 in which six patients underwent successful BMG ureteroplasty without any stricture recurrences at a median follow-up of 24 months. Although this technique was not widely adopted after initial publication, the technique has become increasingly performed after the first reported robotic BMG ureteroplasty by Zhao et al. [41] in 2015. In contemporary series of BMG ureteroplasty, a BMG is generally utilized as an onlay graft rather than a tubularized graft to maximize the chance for graft take [42−44]. In the most robust experience with robotic BMG ureteroplasty to date, Lee et al. [43] reported 54 patients who underwent robotic

BMG ureteroplasty with an 87% success rate at a median follow-up of 27.5 months. The median length of stay was 1 day, and the major (Clavien—Dindo grade >2) complication rate was 5.6%. Of note, the authors emphasized that robotic BMG ureteroplasty was particularly useful after a previously failed ureteral reconstruction as it obviates the need for extensive ureteral mobilization. In the setting of reoperative ureteral reconstruction where there may be obliteration of normal dissection planes and extensive peri-ureteral fibrosis, performing BMG ureteroplasty for a narrowed ureteral stricture allows the surgeon to focus the ureterolysis on only the stricture as the ureter only needs to be prepared for incision rather than excision and anastomosis. After incision of the stricture, the surgeon may onlay a BMG to fill the defect (Fig. 3). When performing BMG ureteroplasty for an obliterated ureteral stricture, the obliterated segment is excised; a backwall of healthy ureteral ends is brought together; and a BMG is anastomosed to the remaining defect (Fig. 4). In this case, the surgeon may limit ureterolysis as only a tension-free plate of ureter must be anastomosed to allow for an onlay BMG, rather than a circumferential anastomosis. The importance of limiting ureteral dissection in the reoperative setting cannot be overstated given the fragile blood supply of the ureter.

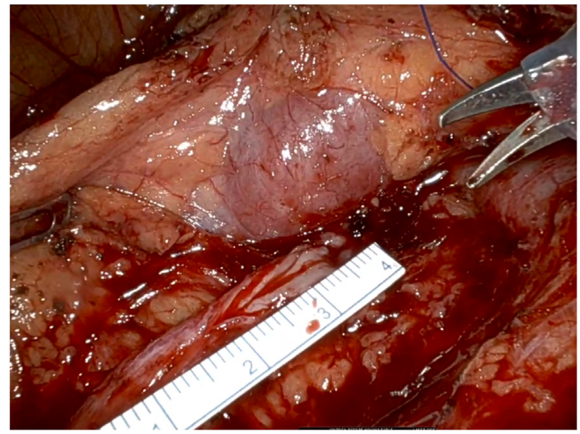

Figure 4 Ureteral stricture excision site for application of buccal mucosal graft.

2.3. UTI

Patients undergoing ureteral reconstruction are at risk for postoperative UTIs given the need to reconstruct a poorly draining urinary system that may be at risk of harboring infected urine. In a review of the American College of Surgeons National Surgical Quality Improvement Program data from 2005 to 2012, Hanske et al. [45] compared 30-day perioperative outcomes in adults undergoing open ($n=170$) versus minimally invasive ($n=423$) pyeloplasty. The authors noted that UTIs occurred in 2.1% of patients undergoing minimally invasive (laparoscopic or robotic) pyeloplasty, and 2.4% of patients undergoing open pyeloplasty ($p=0.865$). In a review of the American College of Surgeons National Surgical Quality Improvement Program data from 2006 to 2013, Packiam et al. [46] compared 30-day perioperative outcomes in adults undergoing open ($n=212$) versus minimally invasive ($n=300$) ureteral reimplantation. The authors noted that UTIs occurred in 5% of patients undergoing minimally invasive (laparoscopic or robotic) ureteral reimplantation, and 11% of patients undergoing open ureteral reimplantation ($p=0.03$).

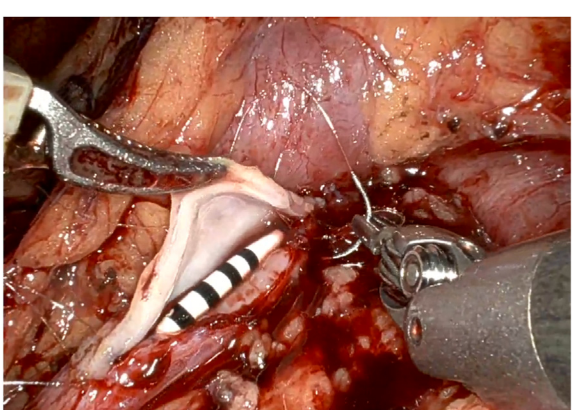

Figure 3 Onlay of a buccal mucosal graft after incision of the ureteral stricture.

Also, patients undergoing ureteral reconstruction may be at risk for UTIs given the perioperative utilization urinary hardware such as a stent, nephrostomy tube, and/or Foley catheter that may be a nidus for infection [31,47]. Kehinde et al. [48] analyzed factors that predisposed patients with indwelling double-J stents to bacterial infection or colonization, by assessing 250 midstream urine samples on the day of stent insertion and removal, and 3—5 cm of stent tip located inside the bladder at time of stent removal. The authors found that longer duration of stenting was associated with higher rates of bacteriuria, as the bacteria rate for stents removed within 30 days was 4.2%, while the rate for stents removed after 90 days was 34% [48]. The authors also found that the rate of bacteriuria was higher in patients with diabetes mellitus (33.3%), chronic renal failure (39.6%), and diabetic nephropathy (44.4%) compared to patients without these conditions (3.3%) ($p<0.001$) [48].

Patients with UTIs following ureteral reconstruction may present with various symptoms, including dysuria, urinary frequency or urgency, fevers and chills, gross hematuria, and abdominal or flank pain. As patients generally have nephroureteral stents after ureteral reconstruction, it may be difficult to differentiate UTIs from stent-related pain and urinary symptoms. Obtaining a urine culture is critical for diagnosis and guiding treatment for UTIs. In patients with a Foley catheter and/or nephrostomy tube, the urine specimen should be obtained from the tubing rather than from the drainage bag. If the index for suspicion for a UTI is high, empiric antibiotics should be initiated while waiting for finalization of the urine culture. We treat all patients with a UTI after ureteral reconstruction with a 10—14 day course of antibiotics. In patients with persistent fevers or abdominal/flank pain, we recommend obtaining cross-sectional imaging to assess for urinary extravasation, urinoma, and abscess formation.

2.4. Compartment syndrome

Compartment syndrome is a rare but potentially morbid complication after ureteral reconstruction. It occurs when increased pressure within an anatomic compartment compromises arterial perfusion to the muscles and nerves within that space. Compartment syndrome after ureteral reconstruction is a type of positional injury due to local ischemia, which damages endothelial cells resulting in leakage of proteins and fluid into the interstitial space. This results in an increase in interstitial pressure, which subsequently elevates compartment pressure, thus perpetuating the cycle of hypoperfusion and tissue ischemia. Patients undergoing ureteral reconstruction in the lithotomy position (often used for distal and middle ureteral reconstruction) are at risk for compartment syndrome in the calf [49], while those undergoing ureteral reconstruction in the flank position (often used for proximal and middle ureteral reconstruction) are at risk for compartment syndrome in the contralateral gluteal and lateral quadriceps muscles [50]. Risk factors for compartment syndrome include obesity, high lithotomy position (legs above the heart), Trendelenburg position, flexion of the operating table, and prolonged operative times [51—53].

If compartment syndrome is left untreated, it may lead to muscle contracture, paralysis, sensory deficits, and even multi-system organ failure [54,55]. Also, compartment syndrome may be accompanied by rhabdomyolysis, which is characterized by breakdown of the muscle that results in the release of myoglobin, lactate dehydrogenase, and creatine kinase into the blood stream, which may cause metabolic acidosis, electrolyte abnormalities that may cause cardiac arrhythmias, and disseminated intravascular coagulation [50,51]. Furthermore, myoglobinuria may lead to acute tubular necrosis, which may cause acute kidney injury, oliguria, and even renal failure [56].

Patients who develop compartment syndrome typically present with severe muscular pain that is out of proportion to examination. Diagnosis of compartment syndrome should be made on a clinical basis based on the patient's medical history, assessment of risk factors, and physical examination. However, when the diagnosis is equivocal, compartmental pressure may be measured and a pressure of greater than 30 mmHg (1 mmHg=0.133 kPa) is diagnostic for compartment syndrome. Treatment of compartment syndrome is emergent surgical fasciotomy in order to minimize the potential for severe complications.

All surgeons performing ureteral reconstruction (and especially those performing complex ureteral reconstruction) should understand risks factors for compartment syndrome and maintain a high index of suspicion in the appropriate clinical setting. In a study by Lee et al. [22] that evaluated multi-institutional intermediate-term outcomes of patients undergoing robotic ureteral reconstruction for long-segment ($\geq$4 cm) strictures in the proximal ureter, 1/20 (5.0%) patient developed compartment syndrome. This patient underwent a robotic ureteroplasty with a BMG, and the authors attributed the development of compartment syndrome to a long operative time (394 min) due to the need for an extensive lysis of adhesions and patient obesity (body mass index: 39 kg/m^2). The patient was managed with fasciotomy. Also, in a multi-institutional review evaluating outcomes after robotic dismembered pyeloplasty by Mufarrij et al. [57], 1/117 (0.9%) patients developed compartment syndrome. This patient, who underwent a 5-h procedure and had a body mass index of 42.4 kg/m^2, required fasciotomy [57]. These reports underscore the importance of understanding risk factors for compartment syndrome such as long operative times and increased body mass index, and prompt diagnosis and management.

3. Complications after ureteral reconstruction utilizing the bladder

3.1. Symptomatic reflux

Adult patients undergoing ureteral reimplantation for ureteral stricture disease generally undergo a refluxing (compared to a non-refluxing) vesicoureteral anastomosis as the current body of literature suggests that it is simpler to perform, and there are no differences in outcomes such as stricture recurrence rates and renal function preservation. In a report by Stefanovic et al. [58] that analyzed 108 patients who underwent ureteral reimplantation of 114 ureters, 71% underwent a refluxing anastomosis and 29% underwent a non-refluxing anastomosis. Forty-one percent of patients who underwent a refluxing anastomosis had reflux, and 9% of patients who underwent a non-refluxing anastomosis had reflux. After 3—18 years of follow-up, there was no differences in renal function preservation (61% refluxing anastomosis versus 74% non-refluxing anastomosis) and ureteral obstruction (22% refluxing anastomosis versus 22% non-refluxing anastomosis). Based on these results, the authors concluded that non-refluxing vesicoureteral anastomosis does not offer any advantage over refluxing vesicoureteral anastomosis in adults for reducing significant complications.

Even in the absence of renal function deterioration and stricture recurrence, patients may become symptomatic with UTIs and/or flank pain secondary to reflux after a refluxing vesicoureteral anastomosis. The literature regarding the need for revisional ureteral reimplantation due to UTIs and/or flank pain secondary to reflux after a refluxing ureteral reimplantation is limited. In a report by Slawin et al. [59] that evaluated outcomes after robotic ureteral reimplantation using a non-transecting side-to-side vesicoureteral anastomosis, 1/16 (6.2%) patients developed persistent pain from urinary reflux and required a revisional non-refluxing ureteral reimplantation.

Despite the seemingly rare nature of symptomatic reflux after a refluxing vesicoureteral anastomosis, we believe that this complication is more common than the literature suggests. At our quaternary referral center, we manage a handful of patients each year with recurrent UTIs and/or chronic flank pain secondary to reflux after refluxing vesicoureteral anastomoses. Such patients typically present with bothersome pain during voiding or recurrent episodes of pyelonephritis. Diagnosis can be made by performing voiding cystourethrogram to determine whether the flank pain is truly from reflux of urine from the bladder into the upper tracts (Fig. 5). If the diagnosis is confirmed, we

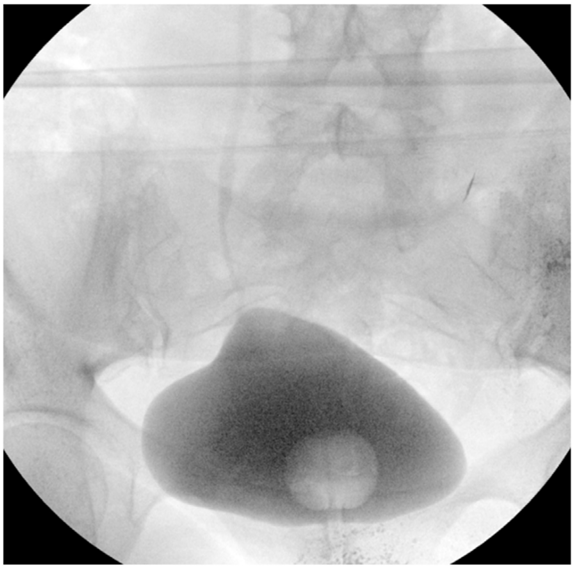

Figure 5 Voiding cystourethrogram showing symptomatic right ureteral reflux during the filling phase after right ureteral reimplantation.

perform revisional ureteral reimplantation with a non-refluxing anastomosis. Further research evaluating the true incidence of symptomatic reflux after non-refluxing vesicoureteral anastomosis is necessary.

3.2. Boari flap necrosis

Boari flap, which involves creating a tubularized bladder flap, is an effective technique used to bridge long segment ureteral defects. In the most robust series to date, Corse et al. [60] evaluated outcomes of 50 patients who underwent robotic Boari flap at three institutions. At a median follow-up of 15 months, there was a 90% success rate. Although creation of a Boari flap is typically associated with high success rates given excellent perfusion to the bladder, a devastating complication when creating any flap is necrosis. This is particularly true in the setting of abdominopelvic radiation, prior surgery, and retroperitoneal fibrosis [61,62]. In a retrospective review by Asghar et al. [62] that evaluated 32 patients who underwent robotic ureteral reconstruction in patients with radiation-induced ureteral strictures, one patient with a history of abdominopelvic radiation and a urinary leak after ureteral reimplantation developed Boari flap necrosis. This patient subsequently required a urinary diversion as the bladder was not able to be salvaged [62].

Even though Boari flap necrosis is a rare complication, it may have potentially devastating consequences. As such, when creating a Boari flap, we prefer to make a wide base flap, that is, as long as the length of the flap. Additionally, we routinely inject 1.5 mL intravenous indocyanine green (25 mg in 10 mL sterile water) and assess flap perfusion under near-infrared fluorescence prior to reconstruction (Fig. 6). If there is tenuous perfusion to the Boari flap, we excise and discard the flap, perform cystorrhaphy, and reconstruct the ureter using a different technique. We believe that these techniques are particularly valuable

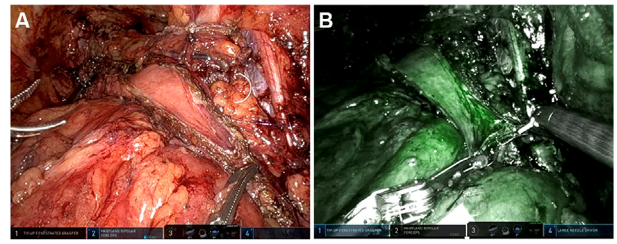

Figure 6 Boari flap perfusion. (A) Difficulty assessing Boari flap perfusion under white light; (B) Boari flap perfusion confirmed after injecting intravenous indocyanine green and visualization under near-infrared fluorescence.

when there are risk factors for compromised blood supply to the bladder (*i.e.*, abdominopelvic radiation, prior surgery, and/or retroperitoneal fibrosis). If there is a small area of flap necrosis, we typically manage using conservative measures such as maintaining Foley catheter, placement of nephrostomy tube, and placement of an interventional radiology-guided drain. If there is a large area of flap necrosis, we typically consider early surgical revision and sometimes cystectomy and urinary diversion formation.

4. Conclusion

Although complications after ureteral reconstruction are uncommon, they may lead to devastating consequences. Having a strong understanding of the potential complications that patients may experience following ureteral reconstruction is critical to adequately counsel patients regarding surgery. Also, this facilitates identification of opportunities for refinements in perioperative management and surgical technique to further improve patient outcomes after surgery. Given the paucity of literature dedicated to complications of ureteral reconstruction, further research is necessary in this space to assist in directing management of complications in an evidence-based fashion.

Author contributions

Drafting of manuscript: Jonathan Rosenfeld, Devin Boehm, Aidan Raikar, Emily Ji, Ziho Lee.
Critical revision of the manuscript: Devyn Coskey, Matthew Lee.

Conflicts of interest

Ziho Lee is a consultant for Boston Scientific, Rolling Meadows, IL, USA and Intuitive Surgical, Sunnyvale, CA, USA. All other authors declare no conflict of interest.

References

[1] Braga LH, Pace K, DeMaria J, Lorenzo AJ. Systematic review and meta-analysis of robotic-assisted versus conventional laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: effect on operative time, length of

hospital stay, postoperative complications, and success rate. Eur Urol 2009;56:848—57.
[2] Buffi NM, Lughezzani G, Hurle R, Lazzeri M, Taverna G, Bozzini G, et al. Robot-assisted surgery for benign ureteral strictures: experience and outcomes from four tertiary care institutions. Eur Urol 2017;71:945—51.
[3] Sukumar S, Sun M, Karakiewicz PI, Friedman AA, Chun FK, Sammon J, et al. National trends and disparities in the use of minimally invasive adult pyeloplasty. J Urol 2012;188:913—8.
[4] 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.
[5] Gadelmoula M, Abdel-Kader MS, Shalaby M, Abdelrazek M, Moeen AM, Zarzour MA, et al. Laparoscopic versus open pyeloplasty: a multi-institutional prospective study. Cent European J Urol 2018;71:342—5.
[6] Klingler HC, Remzi M, Janetschek G, Kratzik C, Marberger MJ. Comparison of open versus laparoscopic pyeloplasty techniques in treatment of uretero-pelvic junction obstruction. Eur Urol 2003;44:340—5.
[7] Bird VG, Leveillee RJ, Eldefrawy A, Bracho J, Aziz MS. Comparison of robot-assisted versus conventional laparoscopic transperitoneal pyeloplasty for patients with ureteropelvic junction obstruction: a single-center study. Urology 2011;77:730—4.
[8] Yohannes P, Chiou RK, Pelinkovic D. Rapid communication: pure robot-assisted laparoscopic ureteral reimplantation for ureteral stricture disease: case report. J Endourol 2003;17:891—3.
[9] Seetharam Bhat KR, Moschovas MC, Patel VR, Ko YH. The robot-assisted ureteral reconstruction in adult: a narrative review on the surgical techniques and contemporary outcomes. Asian J Urol 2021;8:38—49.
[10] Etafy M, Pick D, Said S, Hsueh T, Kerbl D, Mucksavage P, et al. Robotic pyeloplasty: the University of California-Irvine experience. J Urol 2011;185:2196—200.
[11] Sivaraman A, Leveillee RJ, Patel MB, Chauhan S, Bracho JE 2nd, Moore CR, et al. Robot-assisted laparoscopic dismembered pyeloplasty for ureteropelvic junction obstruction: a multi-institutional experience. Urology 2012;79:351—5.
[12] Nie Z, Zhang K, Huo W, Li Q, Zhu F, Jin F. Comparison of urological complications with primary ureteroureterostomy versus conventional ureteroneocystostomy. Clin Transplant 2010;24:615—9.
[13] Whang M, Geffner S, Baimeedi S, Bonomini L, Mulgaonkar S. Urologic complications in over 1000 kidney transplants performed at the Saint Barnabas healthcare system. Transplant Proc 2003;35:1375—7.
[14] Akhavan A, Avery D, Lendvay TS. Robot-assisted extravesical ureteral reimplantation: outcomes and conclusions from 78 ureters. J Pediatr Urol 2014;10:864—8.
[15] Wang Q, Lu Y, Hu H, Zhang J, Qin B, Zhu J, et al. Management of recurrent ureteral stricture: a retrospectively comparative study with robot-assisted laparoscopic surgery versus open approach. PeerJ 2019;7:e8166. https://doi.org/10.7717/peerj.8166.
[16] White C, Stifelman M. Ureteral reimplantation, psoas hitch, and Boari flap. J Endourol 2020;34:S25—30. https://doi.org/10.1089/end.2018.0750.
[17] Meeks JJ, Zhao LC, Navai N, Perry Jr KT, Nadler RB, Smith ND. Risk factors and management of urine leaks after partial nephrectomy. J Urol 2008;180:2375—8.
[18] Kutikov A, Lee M, Lee Z, Uzzo R. Complications of renal surgery. AUA University; 2020. Update Series 39. https://auau.auanet.org/content/update-series-volume-39-2020. [Accessed 1 August 2023].
[19] Wenske S, Olsson CA, Benson MC. Outcomes of distal ureteral reconstruction through reimplantation with psoas hitch, Boari flap, or ureteroneocystostomy for benign or malignant ureteral obstruction or injury. Urology 2013;82:231—6.
[20] Titton RL, Gervais DA, Hahn PF, Harisinghani MG, Arellano RS, Mueller PR. Urine leaks and urinomas: diagnosis and imaging-guided intervention. Radiographics 2003;23:1133—47.
[21] Stolzenburg JU, Rai BP, Do M, Dietel A, Liatsikos E, Ganzer R, et al. Robot-assisted technique for Boari flap ureteric reimplantation: replicating the techniques of open surgery in robotics. BJU Int 2016;118:482—4.
[22] Lee M, Lee Z, Koster H, Jun M, Asghar AM, Lee R, et al. Intermediate-term outcomes after robotic ureteral reconstruction for long-segment (≥4 centimeters) strictures in the proximal ureter: a multi-institutional experience. Investig Clin Urol 2021;62:65—71.
[23] Palese MA, Munver R, Phillips CK, Dinlenc C, Stifelman M, DelPizzo JJ. Robot-assisted laparoscopic dismembered pyeloplasty. J Soc Laparoendosc Surg 2005;9:252—7.
[24] Lee Z, Llukani E, Reilly CE, Mydlo JH, Lee DI, Eun DD. Single surgeon experience with robot-assisted ureteroureterostomy for pathologies at the proximal, middle, and distal ureter in adults. J Endourol 2013;27:994—9.
[25] Selzman AA, Spirnak JP. Iatrogenic ureteral injuries: a 20-year experience in treating 165 injuries. J Urol 1996;155:878—81.
[26] Rasool S, Singh M, Jain S, Chaddha S, Tyagi V, Pahwa M, et al. Comparison of open, laparoscopic and robot-assisted pyeloplasty for pelviureteric junction obstruction in adult patients. J Robot Surg 2020;14:325—9.
[27] Kolontarev K, Kasyan G, Pushkar D. Robot-assisted laparoscopic ureteral reconstruction: a systematic review of literature. Cent European J Urol 2018;71:221—7.
[28] Chow AK, Rosenberg BJ, Capoccia EM, Cherullo EE. Risk factors and management options for the adult failed ureteropelvic junction obstruction repair in the era of minimally invasive and robotic approaches: a comprehensive literature review. J Endourol 2020;34:1112—9.
[29] Kumar M, Singh SK, Arora S, Mittal V, Patidar N, Sureka SK, et al. Follow-up imaging after pediatric pyeloplasty. Indian J Urol 2016;32:221—6.
[30] Lee M, Lee Z, Houston N, Strauss D, Lee R, Asghar AM, et al. Robotic ureteral reconstruction for recurrent strictures after prior failed management. BJUI Compass 2023;4:298—304.
[31] Lee M, Lee Z, Strauss D, Jun MS, Koster H, Asghar AM, et al. Multi-institutional experience comparing outcomes of adult patients undergoing secondary versus primary robotic pyeloplasty. Urology 2020;145:275—80.
[32] Elbaset MA, Zahran MH, Sharaf MA, Elmeniar AM, Ezzat O, Elgamal M, et al. Long term functional success after pyeloplasty for pelvi-ureteral junction obstruction in unilateral poorly functioning kidney in exclusively adults population. Urology 2019;131:234—9.
[33] Mughal S, Soomro S. Pelvi-ureteric junction obstruction in children. J Surg Pakistan (International) 2008;13:163—6.
[34] Wagner M, Mayr J, Häcker FM. Improvement of renal split function in hydronephrosis with less than 10% function. Eur J Pediatr Surg 2008;18:156—9.
[35] Rogers A, Hasan T. Management of secondary pelviureteric junction obstruction. Indian J Urol 2013;29:294—302.
[36] Park J, Kim WS, Hong B, Park T, Park HK. Long-term outcome of secondary endopyelotomy after failed primary intervention for ureteropelvic junction obstruction. Int J Urol 2008;15:490—4.
[37] Vannahme M, Mathur S, Davenport K, Timoney AG, Keeley FX Jr. The management of secondary pelvi-ureteric junction obstruction—a comparison of pyeloplasty and endopyelotomy. BJU Int 2014;113:108—12.
[38] Thomas JC, DeMarco RT, Donohoe JM, Adams MC, Pope JC 4th, Brock JW 3rd. Management of the failed pyeloplasty: a contemporary review. J Urol 2005;174:2363—6.
[39] Hammady A, Elbadry MS, Rashed EN, Moussa A, Gamal W, Dawood W, et al. Laparoscopic repyeloplasty after failed open

repair of ureteropelvic junction obstruction: a case-matched multi-institutional study. Scand J Urol 2017;51:402—6.
[40] Naude JH. Buccal mucosal grafts in the treatment of ureteric lesions. BJU Int 1999;83:751—4.
[41] Zhao LC, Yamaguchi Y, Bryk DJ, Adelstein SA, Stifelman MD. Robot-assisted ureteral reconstruction using buccal mucosa. Urology 2015;86:634—8.
[42] Lee Z, Keehn AY, Sterling ME, Metro MJ, Eun DD. A review of buccal mucosa graft ureteroplasty. Curr Urol Rep 2018;19:23. https://doi.org/10.1007/s11934-018-0772-5.
[43] Lee Z, Lee M, Koster H, Lee R, Cheng N, Jun M, et al. A multi-institutional experience with robotic ureteroplasty with buccal mucosa graft: an updated analysis of intermediate-term outcomes. Urology 2021;147:306—10.
[44] Lee Z, Waldorf BT, Cho EY, Liu JC, Metro MJ, Eun DD. Robotic ureteroplasty with buccal mucosa graft for the management of complex ureteral strictures. J Urol 2017;198:1430—5.
[45] Hanske J, Sanchez A, Schmid M, Meyer CP, Abdollah F, Roghmann F, et al. Comparison of 30-day perioperative outcomes in adults undergoing open versus minimally invasive pyeloplasty for ureteropelvic junction obstruction: analysis of 593 patients in a prospective national database. World J Urol 2015;33:2107—13.
[46] Packiam VT, Cohen AJ, Nottingham CU, Pariser JJ, Faris SF, Bales GT. Open *vs*. minimally invasive adult ureteral reimplantation: analysis of 30-day outcomes in the National Surgical Quality Improvement Program (NSQIP) database. Urology 2016;94:123—8.
[47] Lee Z, Lee M, Lee R, Koster H, Cheng N, Siev M, et al. Ureteral rest is associated with improved outcomes in patients undergoing robotic ureteral reconstruction of proximal and middle ureteral strictures. Urology 2021;152:160—6.
[48] Kehinde EO, Rotimi VO, Al-Awadi KA, Abdul-Halim H, Boland F, Al-Hunayan A, et al. Factors predisposing to urinary tract infection after J ureteral stent insertion. J Urol 2002;167:1334—7.
[49] Kikuchi T, Maeda H. Two cases of compartment syndrome of the lower extremities during surgery for gynecological malignancies. J Anesth 2016;30:481—5.
[50] Reisiger KE, Landman J, Kibel A, Clayman RV. Laparoscopic renal surgery and the risk of rhabdomyolysis: diagnosis and treatment. Urology 2005;66:29—35.
[51] Pariser JJ, Pearce SM, Patel SG, Anderson BB, Packiam VT, Shalhav AL, et al. Rhabdomyolysis after major urologic surgery: epidemiology, risk factors, and outcomes. Urology 2015;85:1328—32.
[52] Stornelli N, Wydra FB, Mitchell JJ, Stahel PF, Fabbri S. The dangers of lithotomy positioning in the operating room: case report of bilateral lower extremity compartment syndrome after a 90-minutes surgical procedure. Patient Saf Surg 2016;10:18. https://doi.org/10.1186/s13037-016-0106-9.
[53] Flierl MA, Stahel PF, Hak DJ, Morgan SJ, Smith WR. Traction table-related complications in orthopaedic surgery. J Am Acad Orthop Surg 2010;18:668—75.
[54] Genthon A, Wilcox SR. Crush syndrome: a case report and review of the literature. J Emerg Med 2014;46:313—9.
[55] Zutt R, van der Kooi AJ, Linthorst GE, Wanders RJ, de Visser M. Rhabdomyolysis: review of the literature. Neuromuscul Disord 2014;24:651—9.
[56] Cervellin G, Comelli I, Lippi G. Rhabdomyolysis: historical background, clinical, diagnostic and therapeutic features. Clin Chem Lab Med 2010;48:749—56.
[57] Mufarrij PW, Woods M, Shah OD, Palese MA, Berger AD, Thomas R, et al. Robotic dismembered pyeloplasty: a 6-year, multi-institutional experience. J Urol 2008;180:1391—6.
[58] Stefanovic KB, Bukurov NS, Marinkovic JM. Non-antireflux versus antireflux ureteroneocystostomy in adults. Br J Urol 1991;67:263—6.
[59] Slawin J, Patel NH, Lee Z, Dy GW, Kim D, Asghar A, et al. Ureteral reimplantation via robotic nontransecting side-to-side anastomosis for distal ureteral stricture. J Endourol 2020;34:836—9.
[60] Corse TD, Dayan L, Cheng N, Brown A, Krishnan N, Mishra K, et al. A multi-institutional experience utilizing Boari flap in robotic urinary reconstruction. J Endourol 2023;37:775—80.
[61] Thompson IM, Ross G Jr. Long-term results of bladder flap repair of ureteral injuries. J Urol 1974;111:483—7.
[62] Asghar AM, Lee Z, Lee RA, Slawin J, Cheng N, Koster H, et al. Robotic ureteral reconstruction in patients with radiation-induced ureteral strictures: experience from the collaborative of reconstructive robotic ureteral surgery. J Endourol 2021;35:144—50.