

Quality assessment of robotic repair of benign ureteral strictures

A Canadian, single-center experience

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ABSTRACT

INTRODUCTION: Endourologic treatments are first-line interventions for short ureteral strictures. With long strictures and endourologic failures, open repair has historically been used; however, robotic-assisted approaches have recently been shown to be effective. As a quality measure, we wanted to assess the performance of robotic ureteral reconstruction compared with open surgical repair during our transition to robotic surgery at a Canadian tertiary care center.

METHODS: From 2011–2024, 43 complex ureteral stricture cases (19 open, 24 robotic) were performed. The primary outcome was six-month success defined by a composite of stent/pain-free status and renogram elimination half-life ($T_{1/2}$). Secondary outcomes included length of stay, operative time, estimated blood loss, and complications.

RESULTS: Success rates at six months were non-significantly different between robotic and open repair (83% vs. 79%, $p=0.36$). Length of stay was shorter in the robotic group (3.1 ± 1.9 vs. 4.9 ± 3.3 days, $p=0.018$). Estimated blood loss (231 ± 84 vs. 244 ± 170 mL, $p=0.30$) and operative time (220 ± 67 vs. 214 ± 74 minutes, $p=0.40$) were comparable between groups. Complication rates were similar between groups.

CONCLUSIONS: Overall, robotic reconstruction yields equivalent six-month success to open repair, with shorter length of stay. These findings support continuing robotic-assisted ureteral reconstruction as a safe and effective alternative to open surgery, offering equivalent short-term success and reduced hospital stay.

INTRODUCTION

Urinary obstruction secondary to benign ureteral stricture is a leading source of patient morbidity, with up to 10% of patients developing a stricture after ureteroscopy.¹ Benign etiologies are varied, including radiation, stones, congenital anomaly, and iatrogenic injury.² Prompt urinary drainage is critical to preventing irreversible renal dysfunction.^{3,4} While endourologic techniques, such as balloon dilation, endoureterotomy, or stenting, are typically the first-line treatments, their failure is not uncommon. A longitudinal, single-center study found that the overall success rate of endourologic treatment was 51.6%.⁵ Failure of endourologic techniques necessitates definitive surgical reconstruction, chronic stenting, nephrostomy tubes, or nephrectomy. Reconstructive surgical options include reimplantation (with or without Boari flap), reanastomosis, or ureteroplasty with flaps or grafts.³

Historically, open reconstruction has been the gold standard for long (>2 cm) ureteral strictures and those that are refractory to endourologic approaches. Open approaches offer high success rates, but are frequently associated with increased pain, prolonged hospital stays, and complications associated with larger incisions.^{6,7} The emergence of laparoscopic and robot-assisted laparoscopic techniques across surgical specialties has consistently offered advantages, including reduced length-of-stay (LOS) and estimated blood loss (EBL).^{8,9} Notably, the highest-volume American center specializing

KEY MESSAGES

- Success rates for robotic and open repair of complex ureteral reconstruction are similar in a Canadian context.
- Robotic repair of complex ureteral obstruction is safe and associated with shorter length of stay.
- Robotic techniques will continue to evolve as experience grows and platforms advance.

in ureteral repair has reported an 87% success rate for robotic buccal graft ureteroplasty.¹⁰

Until now, there have not been any Canadian studies assessing robotic capacity or efficacy compared with open procedures for complex ureteral reconstruction, despite its appeal in high-volume centers in the U.S.¹¹ Furthermore, these referral centers have shown success with robotic repair following failure of open approaches.¹² As a quality measure during our intentional transition from open to laparoscopic-assisted robotic approaches, we studied the efficacy of robotic vs. open repair of complex ureteral strictures at our low-volume Canadian center using the antiquated da Vinci Si™ system. We hypothesize that robotic-assisted ureteral repair can achieve equivalent success rates to open surgery, with a reduced LOS and comparable perioperative outcomes.

METHODS

Study design and setting

With institutional research ethics approval, we conducted a retrospective analysis of upper urinary tract reconstruction procedures from one tertiary institution (London Health Sciences Center) performed by a single urologist with more than two decades of experience with ureteral repair.

Inclusion criteria were cases of upper tract urinary reconstruction from the first time we performed robotic ureteral reconstruction for stricture to our last case with six months of followup (2011–2024), age >18 years, and complexity (defined as prior upper tract urinary reconstruction, multiple strictures, or ureteral defects requiring grafts or flaps). We excluded primary pyeloplasty, ileal interpositions, autotransplants, and cases involving concurrent colorectal or gynecologic

procedures were removed to eliminate comparison of cases that could not have been performed robotically.

Use of robotic or open techniques during this period encompassed an intentional shift from open to robotic techniques based on surgeon preference. Initially, only renal pelvic/proximal ureteral reconstruction was performed robotically, with pelvic cases increasingly added over time, until post-transplant or hostile abdomen became the primary exclusion for consideration of robotic approach.

Surgical approach and techniques were selected based on clinical scenario, ureteral anatomy, and preferences of the surgeon or patient. The da Vinci Si Surgical System™ (Intuitive Surgical, Sunnyvale, CA, U.S.) was used, with a multiport technique for all robotic-assisted procedures. In all cases, ureteral stents were placed intraoperatively and removed 4–6 weeks postoperatively.

Ureteral anastomoses used running 4-0 PDS sutures in all robotic cases, and 5-0 PDS sutures in all open cases. Foley catheters were removed within seven days for distal repairs and within 2–3 days for proximal reconstruction. Drains were removed prior to discharge if there was no evidence of urinary leak. In patients with preoperative nephrostomy tubes, tubes were left in situ and clamped immediately postoperatively as a safety measure. Stents were removed 4–6 weeks following discharge and nephrostomy tubes were removed if there was no obstruction or leak following nephrostogram two weeks after stent removal.

Followup was performed with in-person visits, as well as Lasix renogram assessments of function at six weeks and six months postoperatively. Renal ultrasonography was standardly used in followup (with cystogram in the case of Boari flap).

Data collection and outcomes

Data was collected for the following preoperative characteristics: patient sex, age at date of surgery, etiology, and laterality. The following perioperative parameters were also collected: type of surgical procedure, total operative time, LOS, presence of ureteral stent six months postoperatively, use of ureteral rest (nephrostomy tube drainage without stent preoperatively for at least one week), presence of symptoms six months postoperatively, radiographic or nuclear evidence of obstruction, and complications graded via Clavien-Dindo classification.

The primary outcome was a success rate at six months, defined as a composite outcome: colicky pain (binary) and stent-free status six months post-procedure, and elimination half-life ($T_{1/2}$) <20 minutes in the

postoperative Lasix renogram, if available. Secondary outcomes included operative time, estimated EBL, and LOS. This definition mirrors existing literature on ureteral reconstruction, where success is characterized by symptom resolution or the absence of obstruction on postoperative imaging.^{10,13}

Statistical analysis

Statistical analysis was performed using a two-sample t-test, assuming unequal variances to compare outcomes between the open and robotic surgery groups. A two-tailed t-test was used for our primary outcome. Statistical significance was set at $p < 0.05$. One-tailed Student's t-tests were performed for our secondary outcomes, with an alternative hypothesis of robotic technique superiority.

RESULTS

Patient and surgical characteristics

Our study identified a total of 119 patients, of which 43 (19 open, 24 robotic) met the inclusion criteria. Seventy-six patients were excluded from the following cohorts: concurrent general surgery/gynecology ($n=4$), primary (non-complex) pyeloplasty ($n=69$), and ileal transposition/autotransplant procedures ($n=3$). Within the first five years, 100% of cases were performed in an open fashion, compared to 42% in the last five years (Supplementary Figure 1; available at *cuaj.ca*). Within the last four years, the reasons for open surgery included only bilaterality of proximal ureteral disease and strictures in transplanted kidneys. Initial robotic cases were primarily recurrent ureteropelvic junction obstruction (UPJO); 2022 marked the start of the management of more distal lesions.

Lithotripsy and iatrogenic ureteral resection were identified as the primary etiology of stricture in more than half of all lesions. Patient age and sex appeared balanced (Table 1). Ureteral rest associated with removal of the ureteral stent was obtained in 79% of the robotic cohort compared to 53% of the open cohort ($p=0.038$).

The ureteral lesions appeared to have similar lengths across robotic and open techniques (3.6 cm vs 2.7 cm, respectively, $p=0.080$). The distribution of ureteral lesions appeared to differ across treatment modalities (Supplementary Figure 2; available at *cuaj.ca*).

Success rates

Our study identified very similar success rates of 79–83% ($p=0.36$) at six months across open and

robotic ureteral reconstruction (Figure 1). Additionally, we evaluated success rates by approach over five-year time intervals (Supplementary Figure 3; available at *cuaj.ca*); multivariate regression found neither year nor group significantly contribute to the model.

Failures within the open and robotic cohort occurred in the setting of prior ureteroscopy, transplant, ureteral resection, and UPJO repair failure injury (2:1:1:0, 1:0:1:2, respectively). No failures occurred in the setting of prior radiation.

Table 1. Patient characteristics of those undergoing ureteral reconstruction

	Robot-assisted reconstruction	Open reconstruction
Number	24	19
Age (median)	57	55
Male:female	11:13	10:9
Etiology	Ureteral resection: 6 Lithotripsy: 8 Radiation/RPF: 2 Redo pyeloplasty: 8	Ureteral resection: 8 Lithotripsy: 5 Radiation: 5 Infection: 1
Side (L/R/transplant/bilateral)	14/9/0/1	7/6/5/1
Procedure	Boari flap: 5 Pyeloplasty: 9 Ureteral reimplant: 3 Graft/flap ureteroplasty: 10	Boari flap: 14 Ureteral reimplant: 3 Graft ureteroplasty: 1 Pyeloplasty: 2
Ureteral rest (%)	79%	53%
Post-op renogram available	63%	26%

Multiple procedures were performed for some patients. RPF: retroperitoneal fibrosis.

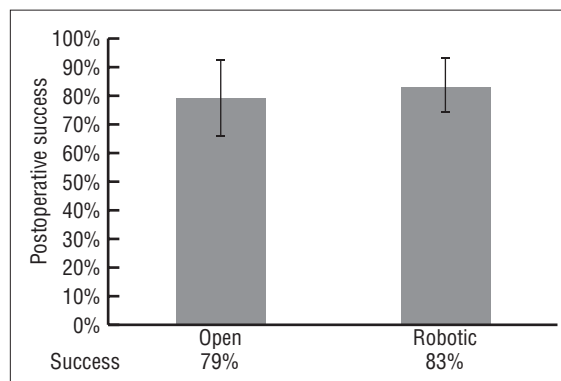


Figure 1. Success rate after ureteral reconstruction.

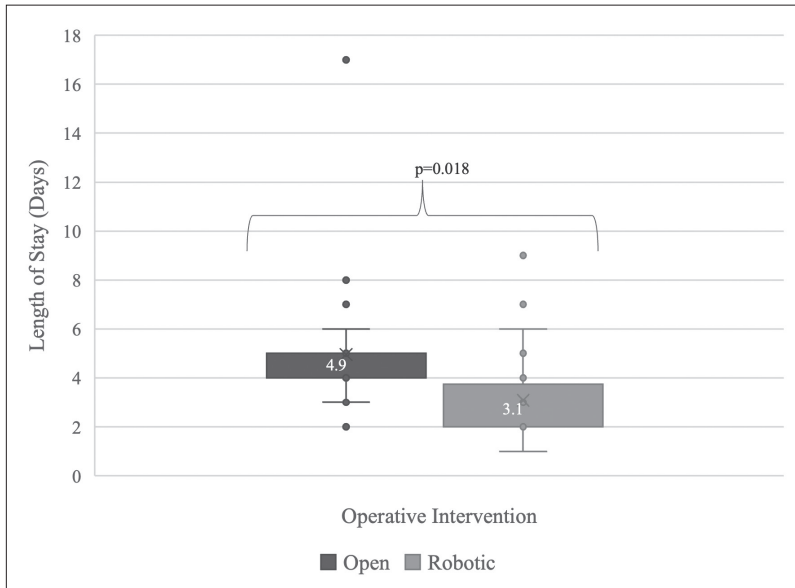


Figure 2. Difference in length of stay (days) by operative technique.

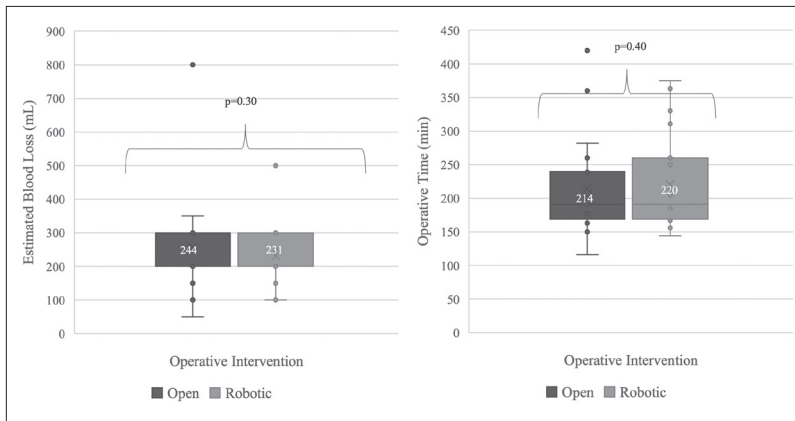


Figure 3. Intraoperative results. No differences were seen between groups.

Perioperative course

Mean LOS was significantly shorter in the robotic group (3.1 vs. 4.9 days, $p=0.018$) (Figure 2). Complication rates were similar: two robotic patients developed urinary leaks requiring extended stenting (one Clavien-Dindo 2, one Clavien-Dindo 3); two open patients developed wound infections (two Clavien-Dindo 2). Both groups had two patients with postoperative urinary tract infections (UTIs). No robotic cases required conversion to open surgery, and no patients in either group required early (<1 month) reoperation.

EBL was comparable between both groups: 231 ± 84 mL in the robotic cohort vs. 257 ± 170 mL in robotic cases ($p=0.30$). No patients in either group required blood transfusion. Mean operative time was not sig-

nificantly different between robotic and open groups: 220 ± 67 minutes and 214 ± 74 minutes, respectively ($p=0.40$) (Figure 3).

DISCUSSION

As our center pivots from open to robot-assisted repairs of complex ureteral injuries over 10 years, we present the first Canadian report demonstrating equivalent efficacy between the two reconstructive modalities. Importantly, our cohort of strictures mirrors existing literature, which indicates that iatrogenic trauma is the most common cause of ureteral injury requiring reconstruction.¹⁴ Furthermore, our open repair success rates appear comparable to the data of a contemporary timeframe (19 open patients, 82% success), despite failure in our cohort also encompassing nuclear scans and stent status.¹⁵ Although our robotic success rates are imperfect, 83% is similar to high-volume, leading world centers.^{10,12,16}

Notably, our retrospective review highlighted a relatively low rate use of ureteral rest, defined by the absence of ureteric stents for at least four weeks before ureteral repair. As data from a multi-institutional cohort demonstrated a 13% absolute increase in operative success (90.7 vs. 77.5%) with ureteral rest, we believe improving our ureteral rest rate remains an area to address in our attempt at quality improvement over the next decade.¹⁷

Within the dataset, robotic procedures had a significantly lower LOS compared to open procedures despite similar operative times. Shorter LOS is known to correlate with patient satisfaction and lower costs for healthcare institutions, making it a valuable metric for evaluating and comparing surgical approaches.^{18,19} The per-diem cost for inpatient services at London Health Sciences Center is \$2666 as of April 2024; this would amount to almost \$5000 in per-case savings.²⁰ These findings align with existing upper tract reconstruction literature, which indicates that robotic-assisted procedures generally result in a shorter LOS compared to open procedures.¹³

Complication rates and EBL were comparable, with only one patient in the robotic cohort experiencing a grade 3 complication. Within some high-volume centers in the U.S., ureteral repair has evolved into a same-day or overnight stay procedure using a single-port system.²¹

Many tertiary care centers in the U.S. have state-of-the-art da Vinci robots in their hospitals, including the daVinci 5 and SP, with virtually all acquiring a daVinci Xi since its release in 2014. Conversely, most Canadian

tertiary centers have only one to two robots per hospital.

Despite having access only to the relatively antiquated and cumbersome da Vinci Si system in our center, we performed a combined robotic proximal (double buccal graft) and distal ureteral reimplant procedure, as well as a simultaneous robotic bilateral ureteral reimplant (Boari and direct reimplant). The recent replacement of the da Vinci Si with the Xi system will transform our ureteral repair technique of choice to robotic in 90% of cases, since all transplant ureteral strictures will now be attempted robotically. With increasing experience in robotic renal transplantation and cystectomy with intracorporeal diversion in Canada, ureteral repair using robotic auto-transplantation and robotic ileal interposition will soon become realities in the Canadian systems.

Limitations

Our sample was from a single surgeon in a setting where complex ureteral reconstruction is not common. This weakened our ability to identify differences between subgroups. This limitation is consistent across the literature, even among multicenter studies, given the specialized nature of complex ureteral reconstruction.¹⁶

As a review of the quality of an intentional surgical pivot from open to robotic repair, this design introduces biases inherent to this retrospective design. The open cohort involved more distal ureteral injuries and therefore a high proportion of reimplants, while the robotic cohort involved a constellation of buccal mucosal grafts, appendiceal onlays, Boari and Scardino Prince flaps, direct reimplants, and uretero-ureteral/renal pelvic anastomoses. Nonetheless, both groups had comparable complexity, as noted by a similar number of radiation or iatrogenic-induced etiologies.

As most of our patients had been referred to our center from other districts, followup beyond six months was limited. Although an endpoint of six months is consistent across much of the literature, it may not capture later recurrences.

Changing perioperative pathways and protocols, such as earlier catheter and drain removal, may have contributed to shorter LOS in the robotic cohort; however, we did attempt to address era-related biases by performing a limited multivariate regression, including operative year and approach, neither of which could significantly contribute to a model. Clear differences in the rate of ureteral rest exist between cohorts, which is likely an artifact of differences in procedure frequency per era.

During the duration of this study, we favored open repair of distal transplant ureters, since we have been encumbered by exclusive access to the da Vinci Si platform. This platform is associated with limited side docking ability and requires greater space to be placed between robotic arms. Therefore, it can be argued that the more challenging and refractory strictures were performed with the open technique.

Our study did not evaluate patient intake of morphine equivalents. During data acquisition, it became clear that access to full pharmaceutical records in our electronic medical record were significantly limited in older patient encounters; to avoid bias, we moved away from this evaluation. Furthermore, back-to-work and patient satisfaction scores were not recorded, but could be very useful in a survey-based, prospective study.

CONCLUSIONS

Preliminary review of the first Canadian series of robotic-assisted complex ureteral repair demonstrates short-term success rates comparable to traditional open surgery and to the success rates of high-volume tertiary centers. Robotic ureteral reconstruction is also associated with similar postoperative safety, with a shorter hospital LOS. This review provides us with data to support continued performance of robotic ureteral repair within the Canadian healthcare system.

COMPETING INTERESTS: The authors do not report any competing personal or financial interests related to this work.

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