A Comparison of Robot-Assisted Laparoscopic Ureteral Reimplantation and Conventional Laparoscopic Ureteral Reimplantation for the Management of Benign Distal Ureteral Stricture

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Purpose: To describe our experience and analyze the outcomes of robot-assisted laparoscopic ureteral reimplantation (RALUR) and conventional laparoscopic ureteral reimplantation (LUR) in treating benign distal ureteral stricture (DUS).

Material and Methods: Patients who underwent RALUR or LUR for DUS were retrospectively analyzed. All surgeries were performed by transperitoneal approach in a refluxing manner. Baseline characteristics, history of previous abdominal surgery, operative profile and follow-up data were collected and analyzed.

Results: Among 68 patients with DUS, 62 were diagnosed with unilateral DUS, including 28 patients underwent RALUR. The mean operative time of the RALUR group was 2.44 ± .45 hours, while the mean operative time of the LUR group was 3.09 ± .74 hours ($P < .001$). The average suturing time of LUR (39.59 ± 3.78 min) is about 2 times that of RALUR (20.04 ± 3.5 min) ($P < .001$). The success rate of the RALUR group and the LUR group were 89.3% and 82.4% respectively ($P = .494$). In multiple linear regression model, the modality of surgery was the only variable that influences operative time (Beta = -.964, $P < .001$), suturing time (Beta = -1.899, $P < .001$) and hemoglobin decline (Beta = -.611, $P = .020$).

Conclusion: Basically, the postoperative outcomes are similar but robotic surgery offers a quicker surgery and anastomosis.

Keywords: anastomosis; laparoscopy; robotic surgical procedures; ureteral obstruction.

INTRODUCTION

The ureteral stricture, which can occur anywhere on the ureter, can result in hydronephrosis, chronic pain or even permanent renal damage. According to the etiology, location and length of stricture, there are various treatment modalities. For the benign distal ureteral stricture (DUS), ureteral reimplantation is considered to be the gold standard treatment modality. After more than half a century of application, the safety and effectiveness of open ureteral reimplantation(OUR) have been recognized by most urologists with long term success rate up to 97% at 45 months[(1)]. The laparoscopy, as a minimally invasive surgery, was first reported for ureteral reimplantation in 4 mini-pigs with bilateral vesicoureteral reflux in 1993[(2)]. It provided advantages over open surgery with more rapid recovery, shorter hospitalization time and better cosmetic appearance[(3)]. After that, the robotic surgical system dramatically improves laparoscopy by providing finer movement and easier intracorporeal suturing. Several studies have compared OUR with conventional laparoscopic ureteral reimplantation(LUR) or robot-assisted laparoscopic ureteral reimplantation(RALUR)[(4-6)]. Our study intends to compare RALUR with LUR by describing our experience of RALUR and LUR for the treatment of DUS.

MATERIALS AND METHODS

A retrospective study was conducted for patients with DUS who underwent LUR or RALUR from January 2014, a year before our hospital was equipped with an operating robot, Intuitive Surgical DaVinci S/Si system®, to December 2018. There was no sampling for this study. The decision for an RALUR or LUR was based on the surgical referral pattern to our hospital rather than specific inclusion or exclusion criteria.
The RALUR and LUR were carried out by two different surgeons, but both with experience of more than a thousand laparoscopic surgeries. All surgeries were

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Table 1. Baseline characteristics of patients with unilateral DUS.

	RALUR	LUR	*P*-value
Gender (male/female)	(9/19)	(13/21)	.790
Age (yrs.)	47.29 ± 12.13	47.53 ± 12.06	.972
BMI (kg/m^2)	23.71 ± 3.37	23.18 ± 2.93	.876
Laterality (left/right)	(17/11)	(14/20)	.202
Gynecologic surgeries			-
Myomectomy	1	1	
Hysterectomy	3	1	
Adnexectomy	1	3	
Urologic surgeries			-
Ureterotomy	0	2	
Cystolithotomy	1	1	
Previous ureteral reimplantation	3	1	-

Abbreviatons: DUS: distal ureteral stricture; RALUR: robot-assisted laparoscopic ureteral reimplantation; LUR: laparoscopic ureteral reimplantation; BMI: body mass index.

performed by transperitoneal approach in a refluxing manner. Before induction of general anesthesia, a Foley catheter was placed. Then the patient was placed in a supine position with the head slightly lower than feet. Four trocars (one 12mm optic trocar, one 12mm trocar and on 8 mm trocar for working arms and one 8 mm conventional laparoscopic trocar) were placed for RALUR. Four trocars (one 12 mm optic trocar, one 12 mm and two 5 mm working trocars) were also placed for LUR. The end of ureter was ligated first. At the junction of dilation and stricture, the distal ureter was transected. After that, about 200mL normal saline was injected into bladder through Foley catheter. The bladder was incised about 1 cm at the lateral dome. The ureter was pulled about 1 cm into the bladder. Both ends of a Double-J tube were inserted into the ureter and bladder respectively. The ureter was then anastomosed to the full thickness bladder wall in a continuous suture pattern with 4-0 absorbable sutures. The absence of leakage of urine was confirmed by injection of normal saline into bladder. At the end of the procedure, a tube was placed for the drainage of abdominal cavity. Antibiotics were used to help prevent urinary tract infection perioperatively.

The drain tube was removed if the output remains minimal, about 3 to 5 days after surgery. The Foley catheter was left in place for about 10 to 14 days. The Double-J tube was removed 2-3 months after discharge under cystoscopy in the outpatient department. All patients were suggested to have ultrasonography and renal function test every six months in the first two years and then annually.

The patients' characteristics, including gender, age, body mass index (BMI), DUS characteristics, abdominal surgical history, details of the operative profile, complications, and post-operative hospitalization time were collected. And follow-up information was also collected by phone.

Statistical analysis was performed by the SPSS 22.0. Continuous variables were presented as mean and standard deviation and compared by using Fisher's exact test. The categorical variables were presented as absolute value and percentages and compared by using Rank-sum test. In a multiple linear regression model, we added a mixture of age, gender, BMI, laterality and the modality of surgery to assess the combined effect of those parameters on the outcomes of patients receiving unilateral reimplantation, including operative time, suturing time and hemoglobin (Hb) decline. The continuous variables in the models were standardized. F-test was applied for testing all coefficients of variables included in the model. Meanwhile, each coefficient of variable was tested by *T*-test. For all statistical tests, if p-value was less than .05, then the difference was considered to be significant.

RESULTS

There were 68 patients who underwent LUR or RALUR. Six of them were diagnosed with bilateral DUS and received bilateral reimplantation. Sixty-two pa-

Table 2. Detail operative profile and follow-up data of patients with unilateral DUS.

	RALUR	LUR	*P*-value
Operative time (hours)	2.44 ± .45	3.09 ± .74	< .001
Suturing time(min)	20.04 ± 3.50	39.59 ± 3.78	< .001
Hb decline(g/L)	8.18 ± 5.30	12.10 ± 5.94	.010
Post-operative hospitalization time (day)	5.54 ± 1.04	5.74 ± 1.78	.912
Follow-up time (months)	27.47 ± 15.37	28.08 ± 16.33	.926
Success rate	89.3% (25/28)	82.4% (28/34)	.494
Complications			
Grade II	7.1% (2/28)	11.8% (4/34)	.681

Abbreviations: DUS: distal ureteral stricture; RALUR: robot-assisted laparoscopic ureteral reimplantation; LUR: laparoscopic ureteral reimplantation; Hb: hemoglobin.

Table 3. The results of multiple linear regression for the outcomes of patients with unilateral DUS.

	Gender			Age			BMI			Laterality			modality surgery		
	Beta	95%CI	*P*	Beta	95%CI	*P*	Beta	95%CI	*P*	Beta	95%CI	*P*	Beta	95%CI	*P*
Operative time(hours)	-.004	-.489, .482	.988	-.036	-.283, .211	.769	.089	-.163, .341	.481	.061	-.419, .541	.799	-.964	-1.443, -.486	<.001
Suturing time(minutes)	.024	-.165, .212	.802	-.054	-.149, .042	.268	.026	-.071, .124	.592	-.115	-.301, .071	.222	-1.899	-2.085, -1.713	<.001
Hemoglobin decline(g/L)	.102	-.419, .623	.696	-.023	-.288, .242	.861	-.074	-.344, .196	.586	.218	-.296, .733	.399	-.611	-1.124, -.097	.021

Abbreviation: BMI: body mass index.

tients who received unilateral reimplantation were included in statistical analysis. All patients presented with decreased renal function, pain or hydronephrosis confirmed by ultrasonography. These 62 patients were divided into two groups according to the operation modality. Among these patients, 34 patients were managed with conventional LUR, and 28 patients were managed with RALUR.

Table 1 shows the baseline characteristics of patients who underwent unilateral ureteral reimplantation. Both groups were comparable in baseline characteristics including age, gender, BMI and laterality. The characteristics of patients who received bilateral ureteral reimplantation were showed in supplementary **Table 1**. Nine patients in each group have received abdominal surgery before. In 14 patients, DUS appeared after their previous abdominal surgeries. Among these surgeries, ten were gynecologic surgeries, including myomectomy, hysterectomy and adnexectomy, eight were urologic surgeries, including ureterotomy and cystolithotomy for urolithiasis. From the previous surgery to symptoms occurred, the time ranged from 1 month to 13 years. In addition, four patients also experienced recurrent DUS after their first ureteral reimplantation.

Table 2 shows the detail operative profile and follow-up data of patients who underwent unilateral ureteral reimplantation. The differences of operative time, suturing time and Hb decline between two group are significant. In the RALUR group, the operative time of 7 (25.0%) patients was less than or equal to 2 hours, and no one had operative time more than or equal to 4 hours. However, in the LUR group, five (14.7%) patients had operative time more than four hours. A patient who received LUR experienced much longer operative time, about 8 hours, than others but similar suturing time due to extensive peripelvic fibrous tissue and scar formation. Fortunately, this patient discharged at the 5th day after surgery without apparent complication. None of these patients needed blood transfusion after operation. According to Clavien Classification of Surgical Complications, three patients in the RALUR group and four patients in the LUR group had Grade II complication. Three patients in the RALUR group and two patients in the LUR group had a fever after surgery, with body temperature over 38□. Two patients in the LUR group were hospitalized for more than 10 days due to hypoproteinemia. One patient in the LUR group experienced urinary leakage, leading to an extension of hospital stay. Three patients in the RALUR group and 7 patients in the LUR group had a Double-J stent placed or balloon dilatation because of recurrent DUS. The ureteral reimplantation of these patients were considered to be failed. All of them didn't receive secondary ureteral reimplantation. Therefore, the success rates of the RALUR group and the LUR group were 89.3% and 82.4% respectively.

The results of multiple linear regression for the outcomes of patients who underwent unilateral ureteral reimplantation are shown in **Table 3**. The RALUR leads to shorter operative time, shorter suturing time and less Hb decline, compared with LUR. In addition, gender, age, BMI and laterality were not influence factors for those outcomes.

DISCUSSION

The iatrogenic injury of the ureter accounts for about 2–10% of all ureteral defects[7]. Some injuries occur during difficult ureteroscopic manipulations or ureterotomy, such as those in 3 patients in our study[7]. Some injuries may also occur during gynecologic procedures, which was reported as the leading cause of iatrogenic DUS[8], such as those in 9 patients in our study. Since the 1960s, OUR has been the standard treatment modality for the benign DUS that was not suitable for endoscopic repair. However, the success rate of endoscopic repair was reported as only 52.6%[9], and the OUR can achieve satisfactory long-term results with success rates over 90%[1,10,11].

Though much satisfactory has gained in OUR, LUR provides some additional advantages such as less intraoperative blood loss and postoperative pain, and more rapid recovery[12]. The first LUR was introduced in 1994 in pediatric patients with vesicoureteral reflux[13]. In the same year, LUR was performed in a 74-year-old man without postoperative intravenous pain medication[14]. A retrospective study compared 10 OUR with 10 LUR and demonstrated significant advantages for LUR in terms of lower estimated blood loss, postoperative analgesic requirement, and shorter hospitalization time[5]. The tamponade effect of the pneumoperitoneum may lessen bleeding from venous plexus. Furthermore, combined with laparoscopic magnification, less bleeding significantly improves visualization for precise dissection and reconstruction[15]. Though feasibility has been repeatedly demonstrated, a large number of studies on LUR highlight the challenging nature, especially difficulties about intracorporeal suturing of the ureter. Sufficient experience with laparoscopy and intracorporeal suturing remains necessary, which leads to the limitation of promotion of LUR.

In recent decades, the presence of robotic platform makes the laparoscopic surgery easier dramatically, particularly reduces the difficulty in intracorporeal suturing by providing 3-dimensional(3D) visualization, precision in instrument movement and six degrees of

freedom. It can also help alleviate perceived difficulties associated with conventional laparoscopy[4]. Similar to other study[16], compared to conventional laparoscopic approach, robot-assisted laparoscopic approach decreases the difficulty in suturing and shortens surgical time obviously. In our study, the operative time and suturing time were influenced by the modality of surgery. Also, a patient in the LUR group had a history of hysterectomy and abdominopelvic radiation therapy. The resultant extensive scaring and adhesions may result in difficulties in trocar placement, exposure and dissection of distal ureter, and extension of the laparoscopic operative times. However, this factor didn't lead to an obvious increase in blood loss. Some studies[17,18] found less estimated blood loss in the LUR group, compared with the RALUR group, while other studies[16] showed an opposing result. It may be influenced by the experience of the surgeon in laparoscopic and robotic techniques. In our study, we found a statistically significant difference in terms of estimated blood loss in favor of RALUR. However, the absolute blood loss difference was about 4g/L hemoglobin, which meant about only 160ml blood loss difference, and the hemoglobin decline might be influenced by the intravenous infusion. Although the p is less than 0.05 and the difference is statistically significant, the clinical difference was not that meaningful. Similar to the study reported by Baldie et al.[18], the difference of post-operative hospitalization time between LUR and RALUR group were not significant in our study.

The key to the success of ureter reimplantation is to achieve a well vascularized, watertight and tension-free anastomosis[15]. Due to the ischemia or excessive tension during ureteral bladder anastomosis, the most commonly postoperative complications are urinary leakage and recurrent distal ureter stricture[1,10,19,20]. In our study, all of the RALUR and LUR were performed by a refluxing modality. No urinary leakage was observed in these patients. In order to avoid reflux and associated potential infection of upper urinary tract, some urologists are more inclined to perform non-refluxing anastomosis. Unfortunately, there remain some problems in non-refluxing manner. One of the traditional anti-reflux managements is submucosal tunnel ureteroneocystostomy[21]. It requires an additional ureteral length, usually about 2 to 3 cm, to accommodate tunneling. However, such length is not always available in some patients. On the other hand, the necessary ureteral length for a tunneled anastomosis may not ensure adequate tissue vascularity, and thus decrease ureteral viability. In addition, tunneled technique is still a challenging point in the laparoscopic approach and leads to more complex intracorporeal suturing and longer operative time. Another anti-reflux modality is nipple technique. Though compared with submucosal tunnel reimplantation, the nipple technique is much easier and less time-consuming, some urologists still tried to modify this manner by extracorporeal tailoring. However, this may result in an inappropriate traction of ureter and elevation of the risk of ischemic damage to the distal ureter. Compared with anti-refluxing manner, the suturing in reflux anastomosis is much easier. In our study, the mean suturing time of LUR was 39 minutes, and even 20 minutes in RALUR. In addition, reflux anastomosis may also avoid ureteral angulation or torsion which is of paramount importance for the success of reimplantation. Nevertheless, due to the possible postoperative reflux, a potential disadvantage of this anastomosis is the tendency toward recurrent pyelonephritis and deterioration in renal function. Fortunately, similar to other studies[22,23], no one experienced complications associated to reflux such as pyelonephritis during their follow-up time in our study. Further support for refluxing anastomoses in this setting may also be extrapolated from the transplant literature, in which fewer cases of ureteral obstruction have been observed among renal transplants with extravesical vs Politano-Leadbetter ureteroneocystostomy24). Although this reflux anastomosis can reduce the chance of recurrence of postoperative stricture in some sense, six patients experienced recurrent strictures during follow-up time and required balloon dilatation or insertion of double-J tube, which may be caused by high-tension anastomosis. Therefore, even in a high-volume center with experience of thousands of laparoscopic urological surgeries, like us, RALUR or LUR remains a challenging surgery.

Because of the retrospective and observational nature and limited amount of cases of this study, selection bias may exist. Due to insufficient sample size of patients who underwent bilateral ureteral reimplantation, statistical analysis didn't make for the data of these patients. The characteristics of these 6 patients received bilateral ureteral reimplantation were described and summarized in the supplementary **Table 1**. The selection of LUR or RALUR in our hospital is mainly based on economic conditions of patients, which may also affect post-discharge care and review. In addition, LUR and RALUR were carried out by different surgeons, thus the difference in surgeon experience may also lead to bias. We also didn't investigate whether the additional cost for the robot is reasonable or worthy for the patients. Besides, all ureteral reimplantation in our study was performed in a refluxing manner, while anti-refluxing manner also plays an important role in this surgery.

CONCLUSIONS

Basically, the postoperative outcomes are similar but robotic surgery offer a quicker surgery and anastomosis. Further high-quality clinical studies, such as randomized clinical trial, are needed to confirm the superior of RALUR. Reflux anastomosis, which requires easy suture, can also achieve high success rate. The differences between LUR and RALUR in anti-reflux anastomosis also need to be compared in the future.

DISCLOSURE OF INTEREST

The authors declared that they have no conflicts of interest to this work.

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