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RESEARCH

Robotic-assisted laparoscopic modified ureteroplasty using lingual mucosa grafts or appendiceal flaps for the management of complex ureteral strictures: a retrospective cohort study

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Abstract

Objective To evaluate the feasibility, safety and efficacy of robot-assisted laparoscopic modified ureteroplasty using a lingual mucosa graft (LMG) or an appendiceal flap (AF) for complex ureteral strictures and summarize our experience.

Methods A total of 16 patients with complex ureteral strictures (range: 1.5–5 cm) who underwent robotic-assisted laparoscopic-modified ureteroplasty and were admitted to our hospital from May 2022-October 2023 were retrospectively analyzed. We used modified presuture methods in patients who needed the posteriorly augmented anastomotic technique to reduce anastomotic tension. Perioperative variables and outcomes were recorded for each patient.

Results The operation under robot-assisted laparoscopy was successfully performed in all sixteen patients (12 with LMG ureteroplasty and 4 with AF ureteroplasty) without conversion to open surgery. The mean length of the ureteral structure was 2.90 ± 0.90 cm (range: 1.5–5 cm), the mean operation duration was 209.69 ± 26.74 min (range: 170–255 min), the median estimated blood loss was 75 (62.5) ml (range: 50–200 ml), and the duration of postoperative hospitalization was 10.44 ± 2.10 d (range: 7–14 d). The follow-up time in this group was 6 ~ 21 months. The success rate of the surgery was 100%.

Conclusion Robot-assisted laparoscopic modified ureteroplasty using AF or LMG is a safe and feasible operation for complex ureteral strictures and deserves to be popularized.

Keywords Ureteral obstruction, Reconstructive surgery, Lingual mucosal graft, Appendiceal flap, Ureteroplasty

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Introduction

The management of long and complex ureteral strictures has always been a challenge in urology. The first minimally invasive treatment for ureteral strictures is endoscopic incision or balloon dilatation [1]. These methods are easy to perform, and patients recover quickly. However, these methods are prone to restenosis, ineffective for long strictures, and cannot be used in complex cases requiring scar tissue resection [2]. The own ureter is the best way, so ureteroureterostomy(end-to-end anastomosis) is the first reconstruction option for short proximal or middle ureteral strictures [3, 4], but if direct anastomosis is not possible, ileal ureteral replacement or autologous kidney transplantation is usually required. However, ileal ureteral replacement and autologous kidney transplantation have serious complications and poor long-term outcomes [5, 6].

Autologous graft ureteroplasty has been widely reported for the repair of complex ureteral strictures [7–15]. This technique results in the formation of a "ureteral plate" via a longitudinal incision of the strictured ureter or transection of the strictured ureter combined with the posteriorly augmented anastomotic technique, after which the autologous graft covers the ureteral defect to complete reconstruction. Its advantages include fewer complications, a high surgical success rate and good long-term results. However, the posteriorly augmented anastomosis technique may be challenging; in some cases, performing low-tension suturing of the posterior wall during the operation is difficult, so we propose a modified method to presuture the posterior wall before transection of the strictured segment to avoid ureteral tears.

Robotic surgery is widely used in ureteral reconstruction because of its unique advantages. In this study, we reported the surgical methods and effects of our center for the treatment of complex ureters through robotic-assisted laparoscopic ureteroplasty using LMG or AF and share our experience with the use of the presuture method in the posteriorly augmented anastomotic technique.

Patients and methods

A total of 16 adult patients who underwent robot-assisted laparoscopic LMG or AF ureteroplasty by the same experienced surgeon between May 2022 and December 2023 were retrospectively enrolled in the study. Persistent clinical symptoms, deterioration in renal function, and radiographic evidence of obstruction were considered indications for surgical intervention. On the basis of the experience of our center, in patients with a length of more than 2 cm where end-to-end anastomosis cannot be performed or in patients with complex ureteral strictures who have restenosis after multiple previous endovascular minimally invasive procedures, we choose LMG or AF ureteroplasty for repair.

All patients underwent urinary ultrasound, CT, antegrade nephrostography and retrograde ureterography to diagnose ureteral stricture and to evaluate the location, length and severity of the ureteral stricture. Antegrade nephrostography and retrograde ureterography revealed ureteral obstruction in 7 patients.

Surgical technique

Routine intestinal preparation, skin preparation, and prophylactic use of antibiotics (second-generation cephalosporins) were performed 30 min before surgery. After successful general anesthesia and tracheal intubation, the patient was placed in the lateral decubitus position (60–70°), with the affected side facing upward. A pneumoperitoneum needle was placed 2 cm from the umbilicus, and CO_2 gas was injected at a pressure of 12–14 mmHg (1 mmHg = 0.133 kPa). After pneumoperitoneum was established, 5 trocars, including 1 camera trocar, 2 robotic trocars and 2 auxiliary trocars, were inserted at point A, point B, point C, point D and point E, as shown in Fig. S1. The locations used in practice depend on the specific stricture location and the patient's body type.

Dissection of the ureteral stricture

The adjacent tissue around the affected ureter is dissected and loosened to ensure adequate exposure of the ureteral stricture. Then, the ureteral stricture was dissected longitudinally, and it was necessary that normal ureteral mucosa could be seen from both ends of the ureter (Fig. 1A). A 5Fr (1 F ≈ 0.33 mm) ureteral stent was used to investigate the ureteral lumen to confirm that it was patent, and the normal ureter was able to pass smoothly through the 10Fr catheter. We can also use a 10Fr catheter to ensure that the ureter is patent.

Posteriorly augmented anastomotic technique

For long ureteral strictures in patients with obstructions, polyps or severe scarring or in patients with recurrent strictures after prior endovascular minimally invasive surgery, the segment of the strictured ureter needs to be resected. We opt for the posteriorly augmented anastomotic technique. Before the stricture ureter was completely transected, the posterior ureter mucosa was presutured at the two healthy ends (Fig. 1B). The two ends of the ureter could be tightened under low anastomotic tension to keep the ureter in good alignment without rotation. After resection of the stricture segment, the dorsal side of the ureter was sutured to form a "ureteral plate" (Fig. 1C and D). To maintain blood flow, the suture is interrupted throughout the procedure. The defect length of the ventral ureter was measured via a ureteral stent with a scale. The placement of a double J (DJ) stent

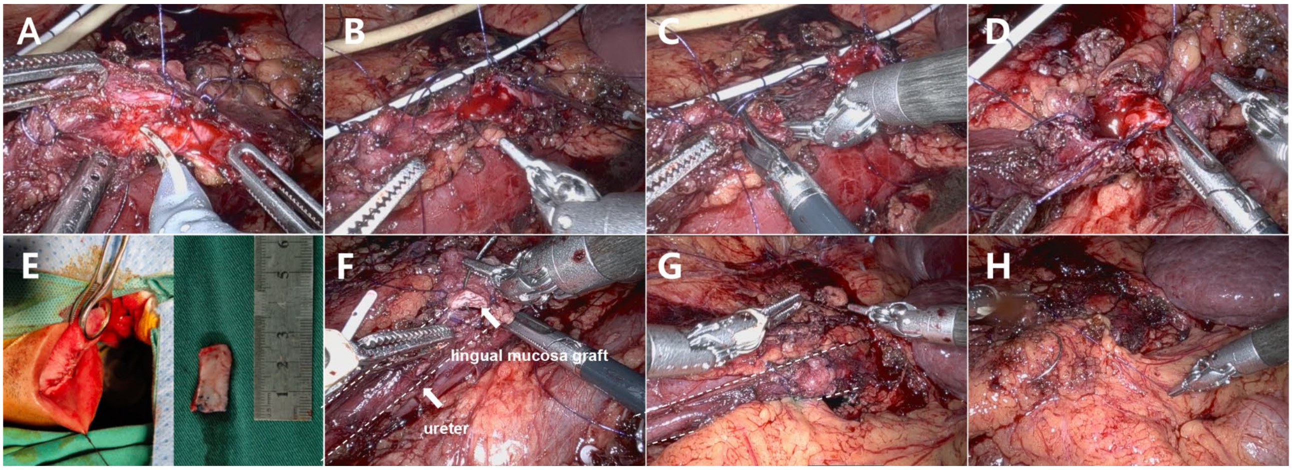

Fig. 1 Posteriorly augmented anastomotic technique with modified presuture methods in LMG ureteroplasty. (**A**) The ureteral stricture was incised in a longitudinal direction. (**B**) The ureteral stricture segment was retained, and the two ends of the healthy ureter were presutured. (**C**) Following the presuture procedure, the stricture segment of the ureter was excised. (**D**) The augmented anastomosis between the two ends of the healthy ureter. (**E**) Anastomosis of the donor site and the prepared LMG. (**F**-**G**) The LMG was anastomosed to the ureteral defect. (**H**) Omental flap wrapping the repaired ureter. LMG = lingual mucosa graft

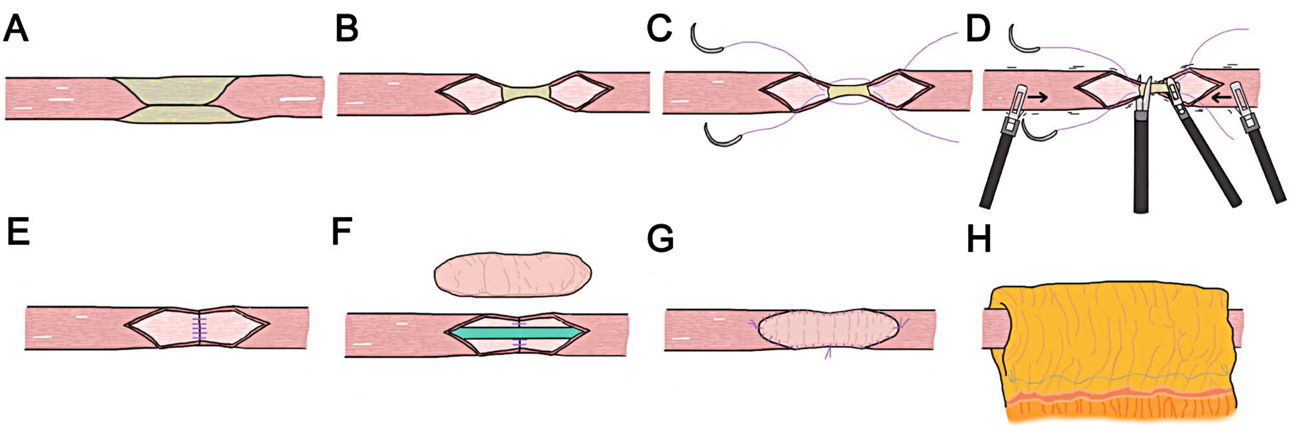

Fig. 2 The schematic diagram of modified presuture technique to avoid anastomotic tension during the posteriorly augmented anastomotic technique. (**A**-**B**) The ureteral stricture was incised longitudinally for visualization of the healthy ureteral mucosa and retention of the ureteral stricture segment. (**C**) The posterior ureter mucosa was presutured at the two healthy ends. (**D**) The distance between the two healthy ureteral ends was reduced, and the stricture segment was resected. (**E**) The posterior wall of the ureter was intermittently sutured. (**F**-**G**) Anterograde placement of the DJ stent, and the defective segment was augmented with the LMG. (**H**) Omental flap wrapping the repaired ureter

via an antegrade method with a supersmooth guide wire is recommended. Figure 2 shows a schematic diagram of our use of modified presuture methods in the posteriorly augmented anastomotic technique.

Lingual mucosal graft ureteroplasty

The length of the lingual mucosal graft that was obtained corresponded to the ureteral defect, and the width was controlled within a range of 1–1.5 cm. Iodophor was used to disinfect the facial and oral mucosa. Methylene blue was used to mark the size of the required lingual mucosal graft. Normal saline was injected under the lingual mucosa, and the required graft was cut along the mark. Bipolar electrocoagulation was used to stop the bleeding. The tongue mucosal wound was closed with 3–0 protein sutures, and gauze was used for packing and compression to stop the bleeding completely. The removed tongue mucosa was moistened with normal saline, trimmed to remove excess fat and muscle tissue, and cut to the appropriate size (Fig. 1E). The trimmed lingual mucosal graft was then placed over the ureteral defect, and one stitch was sutured at each end of the lingual mucosal graft to prevent curling of the graft. Then, the absorption line was used to intermittently suture the incision (Fig. 1F-G). Saline was then injected through the nephrostomy tube to check the watertightness of the anastomosis. The ureteral anastomosis was then covered with an omentum majus to maintain the blood supply to the mucosa and fixed with a 3–0 absorbable suture (Fig. 1H). Finally, a drainage tube is placed close to the anastomotic area.

For patients who did not require the posteriorly augmented anastomotic technique, we incised the stricture longitudinally without transecting the stricture, suspended the ureter with a custom-made puncture suspension needle (Fig. 3A and B), sutured the LMG of the required length at the defect via the two-point method (Fig. 3C), and finally covered the omentum (Fig. 3D).

Appendiceal flap onlay ureteroplasty

The surgical procedure before harvesting the AF is the same as that for LMG ureteroplasty. Care should be taken to observe the morphology and condition of the appendix beforehand to determine whether it can be used. The appendix was separated from the cecum after two Hem-O-Lok clips were placed at the root of the appendix, and care was taken to preserve the mesappendix and blood supply. The appendix is pulled to the defect of the ureter, and the mesangium is separated if necessary to prevent avulsion. The fibers were then detubularized along the antimesenteric border to form an AF whose length was equal to that of the ureteral defect. The AF was placed over the ureteral defect, ensuring that the smooth flap surface faced the lumen, and one stitch was sutured at each end to fix the AF; then, the incision was intermittently sutured (Fig. 3E and H). Figure 4 shows a schematic diagram of LMG ureteroplasty and AF ureteroplasty.

Observation target and complication classification

The operative time, estimated blood loss, postoperative hospital stay, and incidence of complications were recorded. The Clavien−Dindo grading system was used to evaluate intraoperative and postoperative complications [16]. Severe complications were defined as Clavien−Dindo grade III or above.

Postoperative management and followup

The drainage tube was removed after the operation according to the amount of drainage. The Foley catheter was left in place for 1 week, and the patient was followed up in the outpatient clinic for an extended period of time. Urinary system ultrasound and nephro-uretero-bladder radiographs were reviewed at the outpatient clinic one month after surgery to determine whether the DJ stent should be removed. ECT renal function, urinary system ultrasound, urinary system CT urography, anterograde pyelography and ureteroscopy were reviewed in the outpatient clinic 3 months after surgery. The time of the next visit was determined according to the specific conditions. If there were no obvious abnormalities, the nephrostomy tube was removed, and the patients were followed up every 6 months. Success was defined by clinical symptom relief, improvement of hydronephrosis and absence of radiographic obstruction.

Results

As shown in Table 1, a total of 10 males and 6 females, with a mean age of 45.88±9.81 years, were included in the study during the selected period. In 10 patients, the affected side was the left side, whereas in 9 patients, the right side was affected. The strictures were located in the proximal ureter in 10 patients, in the middle ureter in 8 patients, and in the distal ureter in 1 patient. The etiologies associated with ureteral strictures included ureteral

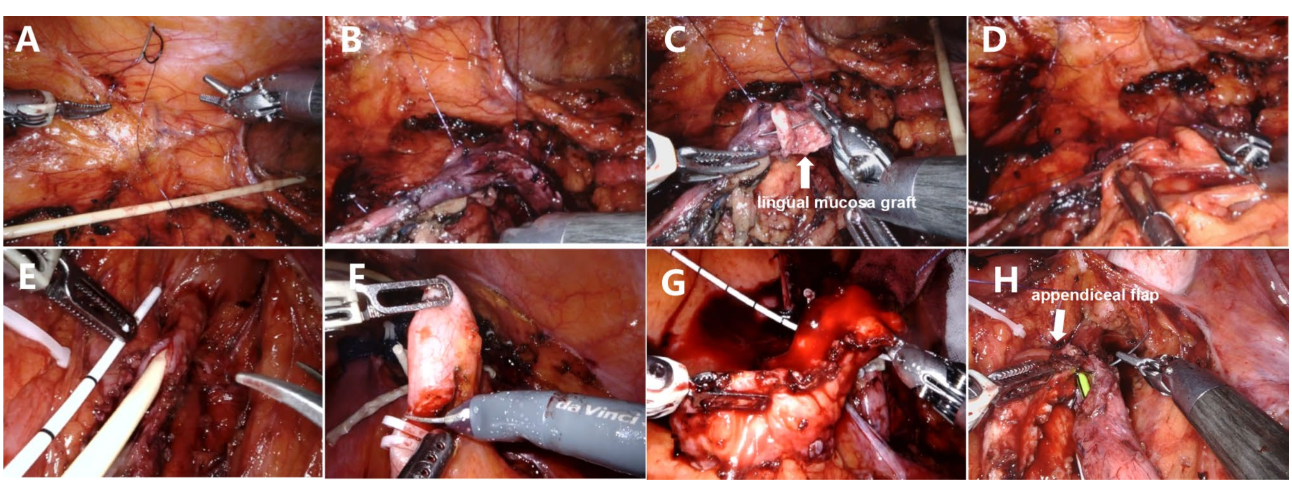

Fig. 3 LMG ureteroplasty and AF ureteroplasty. (**A**-**B**) A custom-made puncture needle was used to suspend the longitudinally incised ureter. (**C**) The LMG was anastomosed to the ureteral defect. (**D**) Omental flap wrapping the repaired ureter. (**E**) The ureteral stricture was incised longitudinally to view the healthy ureteral mucosa, and two ends of the normal ureter could easily pass through the 10 F (1 F ≈ 0.33 mm) ureteral catheter. (**F**) Separate the appendix from the cecum. (**G**) Detubularized along the antimesenteric border to form an AF equal in length to the ureteral defect. (**H**) The AF was anastomosed to the ureteral defect. LMG = lingual mucosa graft, AF = appendiceal flap

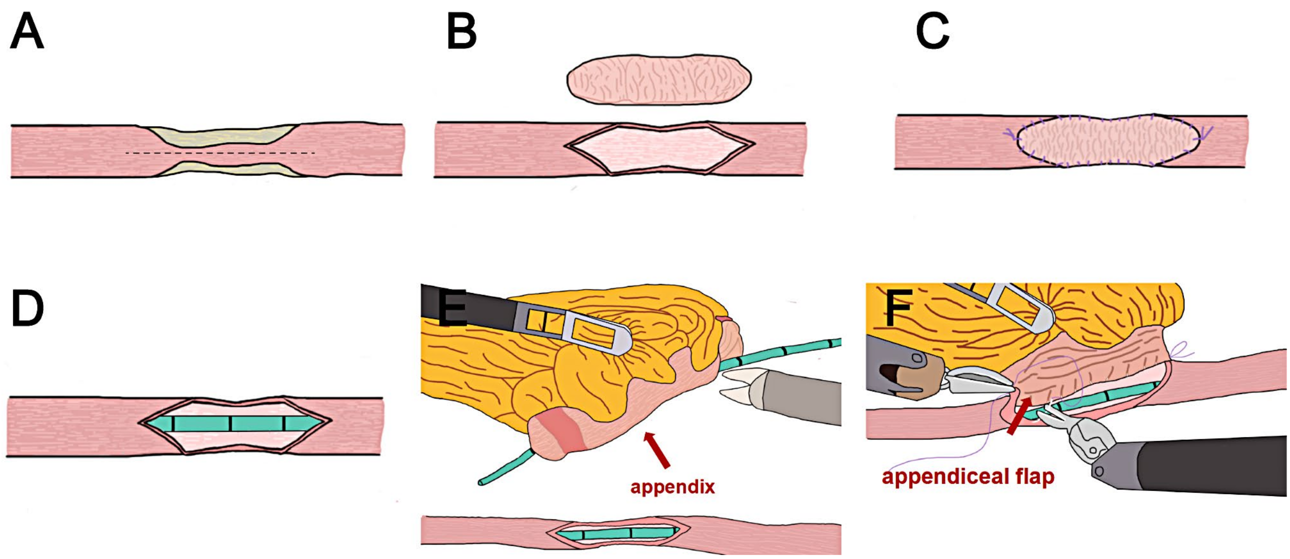

Fig. 4 The schematic diagram of LMG ureteroplasty and AF ureteroplasty. (**A**) The dotted line indicates the location of the longitudinal incision along the length of the ureteral stricture. (**B**) Ureteral defect after longitudinal incision. (**C**) The LMG was anastomosed to the ureteral defect. (**D**) Assess the length of the ureteral defect. (**E**) Procedures of detubularizing the appendix along the antimesenteric border. (**F**) Procedures of the anastomosis between the ureteral defect and AF

Table 1 Patient characteristics

Characteristic	Overall	LMG group	AF group
Number of patients, n	16	12	4
Age, years, mean ± SD	45.88 ± 9.81	46.67 ± 9.39	43.50 ± 12.15
Gender, n (%)	10(62.5)	8(66.7)	2(50)
Male	6(37.5)	4(33.3)	2(50)
Female			
BMI, kg/mm2, mean ± SD	25.17 ± 1.66	24.87 ± 1.71	26.05 ± 1.25
Laterality, n (%)	6(37.5)	6(50)	0(0)
Left	10(62.5)	6(50)	4(100)
Right			
Stricture location, n (%)	10(62.5)	9(75)	1(25)
Proximal	5(31.25)	3(25)	2(50)
Middle	1(6.25)	0(0)	1(25)
Distal			
Obstruction, n(%)	5(31.25)	5(41.7)	0(0)
Stricture etiology, n (%)	15(93.75)	12(100)	3(75)
Ureteral calculi	1(6.25)	0(0)	1(25)
Idiopathic stricture			
History of endoscopic ureteral lithotripsy, n (%)	13(81.25)	10(83.3)	3(75)
Prior ureteral balloon dilatation, n (%)	9(56.25)	9(75)	0(0)
Prior ureteroscopic incision, n (%)	3(18.75)	3(25)	0(0)
Stricture length, cm, mean (range)	2.90 ± 0.90	3.02 ± 0.96	2.55 ± 0.67

calculi (15/16) and idiopathic strictures (1/16). Thirteen patients (75%) had a history of failed previous intracavitary minimally invasive treatment, including ureteral balloon dilatation (9/16) and ureteroscopic incision (3/16). The mean stricture length was 2.90 ± 0.90 cm (range: 1.5 ~ 5 cm).

Preoperative data

The perioperative data of 12 LMG patients and 4 AF patients are summarized in Table 2. All 16 robotic procedures were successfully completed without intraoperative complications or conversion. Among the total number of patients, 12 (75.0%) received augmented anastomosis, with their uterus either obliterated or having a history of failed previous interventions. The mean operation time was 209.69 ± 26.74 min (range: 170–250 min). The mean estimated blood loss was 75 (62.5) ml (range: 50–200 ml). The mean postoperative hospital stay period was 10.44 ± 2.10 days (range: 7 to 14 days). There were no Clavien–Dindo grade II to V complications. Three patients experienced postoperative fever and rapid recovery with antibiotic treatment (Clavien–Dindo I). Two patients in the LMG group had little unclear articulation within 3 days after the operation, but one week after the operation, all patients in the LMG group had accurate articulation and could eat normally. There was no numbness, pain, or difficulty with tongue protrusion at the site of LMG harvest.

Follow-up data

The mean follow-up time was 15.06 ± 4.85 mo (range: 6–21 mo). All patients underwent ureteroscopy and removal of the double-J ureteral stent 3 months after surgery. The ureteroscopic and radiological results revealed that the repaired ureter was smooth throughout (Fig. S2). During the follow-up period, no serious complications, including ureteral stricture, ureteral fistula, or oral tongue mucosa necrosis, were observed in any of the patients.

Table 2 Perioperative data of patients

Variable	Overall	LMG group	AF group
Augmented anastomosis technology, n(%)	12(75.0)	10(83.3)	2(50.0)
Operative time (min), mean ± SD	209.69 ± 26.74	214.58 ± 206.06	195.00 ± 26.06
Estimated blood loss (ml), median (range)	75(50 ~ 200)	87.5(50 ~ 200)	75(50 ~ 150)
Postoperative hospital stays (days), mean ± SD	10.44 ± 2.10	10.17 ± 2.08	11.25 ± 2.22
Postoperative complications, n (%)	3(18.8)	3(25.0)	0(0.0)
Follow-up time (months), mean ± SD	15.06 ± 4.85	16.75 ± 4.12	10.00 ± 3.16
Success rate, n (%)	16(100)	12(100)	4(100.0)

Discussion

Long and complex ureteral strictures have always been challenging problems for urological surgeons. At present, the reported repair of ureteral strictures by autologous grafts avoids the serious complications of traditional operations, such as autologous kidney transplantation and ileal ureteral surgery, reflects good clinical effects and gradually solves this problem.

Commonly used autologous grafts include oral mucosa grafts (LMGs and buccal mucosa grafts [BMGs]) and AFs. Oral mucosa grafts are among the most widely accepted restorative materials with good overall toughness, easy survival, resistance to urinary erosion and few related complications [17]. There is no significant difference in oral complications after mucosal graft harvest between LMG and BMG [18]. However, harvesting the BMG may cause serious complications, such as difficulty in opening the mouth and blockage of the salivary duct [19], whereas the flank and ventral sides of the lingual region have no special function; thus, theoretically, LMG have fewer complications than BMG do. The LMG is convenient for harvesting, and part of the tongue can be pulled out of the mouth during harvesting, which is more suitable for patients whose mouth is difficult to open [11]. Considering the advantages of the LMG, we usually use the LMG in the oral mucosa graft to repair ureteral strictures. The advantage of AF is that its absorptive and secretory functions are weak, and the risk of electrolyte imbalance and mucus embolism after surgery is low [9, 13]. In addition, the AF preserves the original blood supply, the risk of ischemic necrosis is theoretically low, and the diameter and location of the appendiceal tube are similar to those of the right ureter. However, the AF is only suitable for reconstruction of right ureteral strictures or patients unable to undergo oral mucosa grafts repair. And patients with inflammation of the appendix, insufficient length and diameter of the appendix, previous appendectomy, or other possible adverse factors, the AF is not suitable for repair.

Currently, there is no uniform definition of long ureteral stricture, which is generally considered to be a stricture greater than or equal to 2 cm. Our center believes that the ureteral stricture that cannot be completed for primary end-to-end anastomosis is called long ureteral stricture, and such patients may be considered for ureteroplasty using autologous grafts. It's worth noting that LMG and BMG might be also used in complicated UPJ-stenosis. But for distal ureteral strictures, we recommend use ureteral reimplantation, if the ureteral length is insufficient for direct reimplantation, additional length can be obtained by ureteral reimplantation with psoas hitch or Boari flap [20, 21]. Studies have shown that for patients with ureteral strictures without obstruction, longitudinal incisions of the stricture segment is preferred. For patients with obstruction or hard scar tissue, resection of the diseased ureter is performed via the posteriorly augmented anastomotic technique [8, 11, 12]. According to the experience of our center, for patients with complex ureteral strictures who have undergone many intralesional minimally invasive treatments, a longitudinal incision of the stricture segment alone cannot remove the diseased segment of the ureter, and there is a possibility of restricture after surgery; thus, we adopt the posterior extended anastomosis technique to avoid stricture recurrence. The difficulty of this technique is the low-tension anastomosis of the posterior wall of the ureter after resection of the diseased segment. The traditional surgical method involves resecting the narrow segment and then performing posterior wall anastomosis. Posterior wall anastomosis often has high tension, which can lead to the risk of ureteral rupture. Our center proposed that while preserving the proximal and distal sides of the narrow segment, the normal two ends of the ureter connected by the posterior wall should be presutured first; then, the two ends of the anastomosis could be tightened under low anastomotic tension to maintain good alignment and nonrotation of the two ureteral segments, and subsequently, the narrow segment could be removed. This method can effectively reduce anastomotic tension and prevent the normal ureter of the posterior wall from being unable to connect under high tension.

Our center summarizes the surgical experience as follows: (1) Robotic suturing is used for intermittent suturing of the autologous graft covering the ureteral defect without continuous suturing to keep the blood supply of the patch infiltrated and effectively avoid the anastomotic stricture. (2) The difficulty in treating ureteral stricture patients lies in the easy occurrence of restricture.

Therefore, we used a posteriorly augmented anastomotic technique to treat patients who had undergone multiple previous endovascular minimally invasive procedures to reduce ureteral distortion and stricture recurrence. (3) If the stricture segment is too long (>6 cm) to connect the posterior wall of the ureter with low tension, a longitudinal incision of the stricture segment may be attempted to repair the posterior wall to maintain posterior wall continuity, reduce anastomotic tension, and reduce the risk of postoperative urinary leakage. (4) To ensure adequate blood supply to the incision, the greater omentum or perirenal fat with blood supply was sutured around the repaired ureter.

Limitations

The postoperative hospitalization days of patients in this study were slightly longer than those in other centers, mainly for two reasons. First, we usually discharged patients after suture removal (7–9 days after surgery) and bladder catheter removal (if there was no significant fluid accumulation on abdominal ultrasound after surgery, we chose to remove the bladder catheter about 10 days after surgery). Second, most of our patients have idiopathic stricture, which makes them more worried about their condition and they asked for a longer hospital stay. The above reasons may affect the postoperative hospital stay, and we will further optimize our treatment strategy in the future to reduce the postoperative hospital stay of patients. In addition, the current follow-up time of this study is relatively short, although the short-term success rate shows a good effect, further longer follow-up is still needed to prove the effectiveness of this surgery, and accurate evaluation of complications, recurrence rates and overall patient satisfaction.

Conclusion

Robotic-assisted laparoscopic-modified ureteroplasty using AF or LMG for the treatment of complex ureteral strictures has no serious complications, and the short-term postoperative effect is good, indicating that it is a safe and feasible operation. We propose that the modified ureteral presuture of normal double ends before resection of the stricture segment can effectively reduce anastomotic tension and prevent ureteral tear. Moreover, we clarify that the posteriorly augmented anastomotic technique can be performed in patients with complex ureteral strictures of appropriate length, which can effectively prevent the recurrence of postoperative strictures. However, the maximum length of the stricture segment that can be removed needs further investigation. Owing to the limited sample size of the surgical design, the conclusions need to be further verified in a large sample size, multicenter, randomized controlled trial.

Abbreviations

LMG Lingual mucosa graft
AF Appendiceal flap
BMG Buccal mucosa graft

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-024-02601-1.

Supplementary Material 1: Fig. S1: Patient position and port placement for robot-assisted laparoscopic ureteroplasty (left side, for example).

Supplementary Material 2: Fig. S2: Comparison of preoperative and postoperative findings in a patient with a complex ureteral stricture repaired by robotic-assisted modified LMG ureteroplasty. (A) Left pyelography and left retrograde ureterography revealed an obstruction of the middle ureter. (B) Left anterograde pyelography revealed no dilatation of the left renal pelvis and no significant stricture of the left ureter 3 months after surgery. (C) Ureteroscopy revealed that the left ureter was patent and that the mucosa was healthy 3 months after surgery. LMG = lingual mucosa graft.

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Author contributions

All the authors participated in the operation and contributed to the writing of the manuscript. W Wang provided study materials or patients. H Xu, C Yang and S Zeng contributed to the collection and assembly of the data. H Xu and J Ye contributed to the data analysis and interpretation. All the authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The protocol for this research project was approved by a suitably constituted ethics committee of the institution and conforms to the provisions of the Declaration of Helsinki. Committee of the General Hospital of Southern Theater Command, Approval No. NZLLKZ2023137. Informed consent was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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