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Original Article

Minimally invasive reconstruction of extensive mid-lower ureteral strictures using a bilateral Boari flap

Shuaishuai Chai [a,1], Hao Zhang [b,1], Gong Cheng [b], Jiawei Chen [b], Xincheng Gao [b], Yuancheng Zhou [b], Xingyuan Xiao [a,*], Bing Li [a,*]

[a] *Department of Urology, Zhongnan Hospital of Wuhan University, Wuhan, China*
[b] *Department of Urology, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China*

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Abstract *Objective:* To describe and evaluate the technique using bilateral Boari flap ureteroneocystostomy (BBFUNC) for bilateral mid-lower ureteral strictures.
Methods: We retrospectively reviewed five patients who underwent minimally invasive BBFUNC in our institution (Union Hospital, Wuhan, China) between July 2019 and December 2021. The bilateral ureters were mobilized and transected above the stenotic segments. The bladder was isolated and incised longitudinally from the middle of the anterior wall. Then, an inverted U-shaped bladder flap was created on both sides, fixed onto the psoas tendon, and anastomosed to the ipsilateral distal normal ureter. Following double-J stenting, the Boari flaps were tubularized, and the bladder was closed with continuous sutures. The patients' perioperative data and follow-up outcomes were collected, and a descriptive statistical analysis was performed.
Results: No case converted to open surgery, and no intraoperative complication occurred. The median surgical time was 230 (range 203–294) min. The median length of the bladder flaps was 6.2 (range 4.3–10.0) cm on the left and 5.5 (range 4.7–10.5) cm on the right side. All patients had not developed recurrent ureteral stenosis during the median follow-up time of 17 (range 16–45) months and had a normal maximum flow rate after surgery. The median post-void residual was 7 (range 0–19) mL. The maximal bladder capacity was decreased in one (20%) patient.

* Corresponding author.
E-mail address: 114714259@qq.com (X. Xiao), bingli2023@whu.edu.cn (B. Li).
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[1] Both authors contributed equally to this work.

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Conclusion: The present study demonstrates that minimally invasive BBFUNC is feasible and safe in treating bilateral mid-lower ureteral strictures, and the impact on lower urinary tract function is limited.

1. Introduction

Bilateral mid-lower ureteral strictures (BMLUS) are challenging conditions in ureteral reconstruction. Patients with BMLUS usually have a history of repeated ureteral lithotripsy, radical hysterectomy, pelvic radiotherapy, or even recurrent strictures after surgical repair. The ureteral stenosis presents high stricture locations and severe pelvic adhesions, making it difficult to separate the diseased segments and repair the ureters with bilateral ureteral reimplantation. Ileal ureter replacement (IUR) is the main surgical treatment for BMLUS, while the method is complex and associated with considerable complications [1]. The bilateral Boari flap ureteroneocystostomy (BBFUNC) provides another option for patients with BMLUS. However, such techniques, especially the minimally invasive approach, have rarely been reported. Here, we present our experience and postoperative follow-up outcomes in a case series of five patients undergoing laparoscopic BBFUNC (L-BBFUNC) or robot-assisted BBFUNC (RA-BBFUNC), hoping to shed new light on the clinical application of the technique.

2. Patients and methods

2.1. Study population

Between July 2019 and December 2021, five patients who underwent BBFUNC in our institution (Union Hospital, Wuhan, China) were included in the retrospective review, including two RA-BBFUNC cases and three L-BBFUNC cases (using laparoscopy or a robot chosen by the patients). All patients' written informed contents have been obtained. The indication for BBFUNC was benign BMLUS that was not amenable to ureteral reimplantation or psoas hitch. The mid ureter was defined as between the proximal and distal edge of the sacrum [2], and the lower ureter was between the distal sacral border and the ureteral orifice. Our study was approved by the institutional ethics review board (Union Hospital, Wuhan, China; approval number 2021—1059) and that has been conducted in accordance with the principles set forth in the Helsinki Declaration, and all procedures were performed by the same surgeon (Li B) using the da Vinci Si Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) or traditional laparoscopy.

The preoperative characteristics of the patients are shown in Table 1. All patients had a normal bladder volume (>300 mL) without neurogenic bladder or non-functioning kidney. Cases 1, 2, and 5 had a history of gynecological malignancy, while the tumor was clinically cured and recurrence-free for over 2 years. Strictures in Case 3 were secondary to bilateral endoscopic ureteral lithotripsy and were treated with repeated ureteral stenting and percutaneous nephrostomy before surgery. Cases 4 and 5 also had a history of repeated ureteral stenting. Nevertheless, none of the cases had undergone ureteral surgical repair before.

2.2. Preoperative preparation

At least 2 weeks before surgery, four of the five cases underwent bilateral percutaneous nephrostomy, and the ureteral stents were simultaneously removed to allow the ureteral tissue to rest. Then, after the disappearance of ureteral edema in 2 weeks [3], bilateral antegrade and retrograde urography were performed to locate and evaluate the ureteral stricture segments. Case 5 rejected nephrostomy; the double-J stents were removed 2 weeks preoperatively; and the stricture segments were located by CT urography. The hydronephrosis was assessed according to the Society for Fetal Urology grading system [4] with CT urography or ultrasonography. The bladder morphology, capacity, and vesicoureteral reflux (VUR) were assessed by preoperative voiding cystourethrogram (VCUG). Specifically, we gradually instilled contrast agent into the bladder through a 10 Fr catheter until the bladder was fully distended, and the patients experienced a strong urge to urinate. This allowed us to obtain bladder capacity data. Subsequently, we assessed lower urinary tract (LUT) function by observing dynamic imaging of bladder voiding activities. Based on these evaluations, we recommended the bilateral Boari flaps surgery to the patients. In addition, ^{99m}Tc-diethylenetriaminepentaacetic acid renography was performed in all patients to assess the split renal function.

2.3. Surgical technique

The patient was placed in a 30-degree Trendelenburg position, with the legs abducted. For RA-BBFUNC, the robot was positioned caudal to the patient between the legs. The 12-mm camera port was placed through a supra-umbilical incision in the median line, and the distance from the umbilicus was adjusted depending on the location and length of the ureteral stricture. Two 8-mm robotic ports were bilaterally placed along the midclavicular line, and two fingertips caudal to the camera port. The third 8-mm robotic port was inserted a handbreadth (10 cm) lateral to the other ipsilateral robotic port. The position of two assistant ports (5 mm and 12 mm) were illustrated in Fig. 1A. For L-BBFUNC, the 10-mm camera port was inserted at the upper edge of the umbilicus and could also be slightly changed according to the specific location of stricture. Two operating ports (10 mm and 5 mm) were separately placed at the lateral border of the rectus abdominis on bilateral sides (Fig. 1B).

Table 1 Preoperative patient characteristics.

Patient characteristic	Case 1	Case 2	Case 3	Case 4	Case 5	Median (range)
Age, year	49	46	55	34	55	49 (34–55)
Gender	Female	Female	Male	Male	Female	–
BMI, kg/m^2	18.6	18.0	27.0	27.0	24.0	24.0 (18.0–27.0)
Etiology	RH	CRT	Bilateral EUL	EUL for left; CO for right	RH and CRT	–
Preoperative symptoms	Fever and vomit	Nausea, vomiting, and urinary urgency and frequency	None	Left flank pain	Bilateral flank pain	–
Stricture location[a]						
Left	S3	S2	S3	S2	L5	–
Right	S3	S1	S2	S2	L5	–
Preoperative hydronephrosis[b]						
Left	Grade 3	Grade 2	Grade 4	Grade 2	Grade 3	–
Right	Grade 3	Grade 3	Grade 2	Grade 4	Grade 3	–
Preoperative SRF, mL/min						
Left	33.7	46.3	9.6	55.6	47.4	46.3 (9.6–55.6)
Right	35.7	21.4	74.6	45.0	49.8	45.0 (21.4–74.6)

BMI, body mass index; RH, radical hysterectomy; CRT, chemoradiotherapy; EUL, endoscopic ureteral lithotripsy; CO, congenital obstruction; S, sacrum; L, lumbar; SRF, split renal function; –, not applicable.
[a] Vertebral segment.
[b] According to the Society for Fetal Urology grading system.

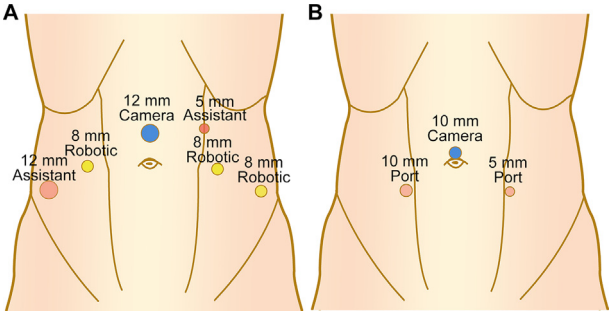

Figure 1 Port placement. (A) Robot-assisted BBFUNC; (B) Laparoscopic BBFUNC. BBFUNC, bilateral Boari flap ureteroneocystostomy.

Both RA- and L-BBFUNC used a transperitoneal approach, and the main steps were identical. After mobilization of the colon, the ipsilateral ureter was identified at the bifurcation of the common iliac artery and was isolated caudally until the identification of the stenotic segment. Usually, identifying the stenotic segments was difficult in patients with extensive pelvic adhesions and fibrosis. Our strategies to precisely position the stenotic site are as follows. First, before surgery, we adequately evaluated ureteral strictures by anterograde and retrograde urography. Second, bilateral nephrostomy tubes were clamped preoperatively to dilate the normal distal ureter. Finally, if the ureteral dilatation and peristalsis remain insignificant during surgery, an intravenous bolus of 10 mg furosemide or injecting diluted methylene blue through the nephrostomy tubes is useful. Special attention should be paid to preventing iliac vessel injury during the dissection.

After mobilizing and exposing the proximal diseased ureter and normal distal ureter, the ureter was transected above the stricture with the distal stump ligated and the proximal stump spatulated. A 10 Fr catheter was used to detect the patency of the normal distal ureter (Fig. 2A). The contralateral side was processed similarly. After that, the bladder was filled with 250 mL of saline through the catheter and mobilized as distal as possible on both sides after dissecting the peritoneum and bilateral bladder pedicle. The anterior bladder wall was incised longitudinally from the middle. Then, an inverted U-shaped bladder flap was created on both sides based on the length of ureteral defects with the length–width ratio of less than 2:1 [5,6] (Fig. 2B and C). Both flaps were fixed onto the psoas tendons and were anastomosed to the ipsilateral proximal ureteral stump with interrupted 4–0 absorbable sutures in a tension-free fashion (Fig. 2D). Following double-J stenting, the Boari flaps were tubularized with 4–0 barbed sutures (Fig. 2E), and the bladder incision was closed with continuous 3–0 barbed sutures in two layers. Finally, the bladder was inflated with 150 mL of saline to exclude leakage (Fig. 2F), and a drainage tube was placed.

2.4. Postoperative management and follow-up

For postoperative management, the Foley catheter was removed 5–7 days after surgery, and the drainage tube was removed when the output was less than 50 mL per day with no concerns of urinary extravasation [3]. The double-J stents were removed 4–5 weeks after surgery, and the nephrostomy tubes were left until bilateral antegrade urography was performed 1 week later. Further follow-up visits included symptomatic assessment, VCUG, ultrasonography, diethylenetriaminepentaacetic acid renography, and LUT function evaluation (including post-void residual, maximum flow rate, and maximal bladder capacity). Surgical success was defined as the absence of stenosis

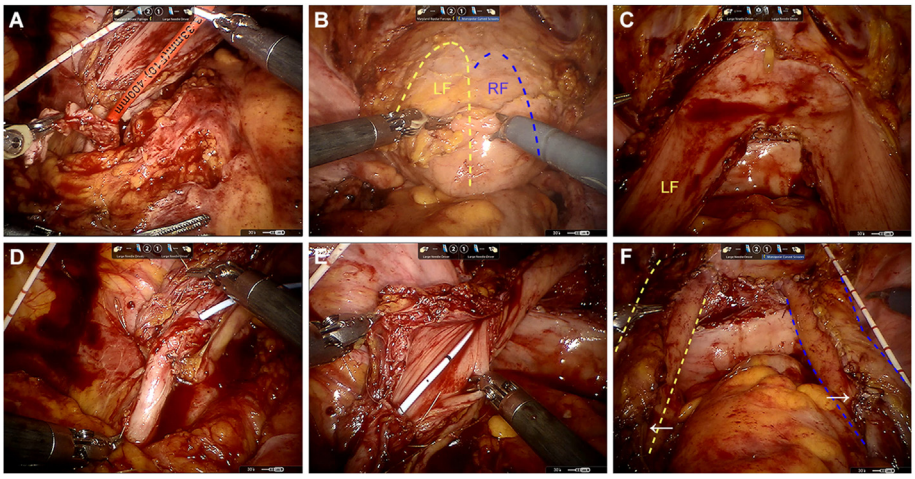

Figure 2 Main steps of robot-assisted bilateral Boari flap ureteroneocystostomy. (A) After the bladder was fully dissociated, an inverted U-shape Boari flap was fashioned on both sides according to the length of ureteral defects with a broad base; (B) The Boari flaps were fixed to the ipsilateral psoas muscle; (C) A 10 Fr catheter was used to detect the patency of the proximal ureteral stump before anastomosis; (D) The Boari flap was anastomosed to the ipsilateral ureter after double-J stenting; (E) The Boari flaps were tubularized, and the bladder incision was closed; (F) A leakage test was performed. The ureterovesical anastomosis sites were marked by white arrows. The yellow and blue dash line represented the left and right bladder muscle flaps, respectively. LF, left flap; RF, right flap.

symptoms and no obstruction on imaging tests. The follow-up regime was 3 months, 6 months, 12 months, and 18 months postoperatively and then yearly.

3. Results

Table 2 presents the perioperative data. No case converted to open surgery, and no intraoperative complication occurred. The median operative time was 230 (range 203—294) min, and the median estimated blood loss was 80 (range 40—150) mL. The median length of the bladder flaps was 6.2 (range 4.3—10.0) cm on the left and 5.5 (range 4.7—10.5) cm on the right side. The median postoperative hospitalization was 6 (range 6—7) days.

The median follow-up time was 17 (range 16—45) months. The postoperative symptoms are shown in Table 2. Urography revealed preoperative ureteral strictures (Fig. 3A and B) and the patency of the postoperative vesicoureteral anastomosis (Fig. 3C), and the hydronephrosis was alleviated to varying degrees in all cases (100%; Table 2; Fig. 3D and E). The split renal function was improved in Cases 1, 3, and 5 after surgery (60%; Tables 1 and 2) and had no significant change in the remaining two cases. In addition, all patients had a normal maximum flow rate, and the median post-void residual was 7 (range 0—19) mL after surgery. The maximal bladder capacity was normal in four of the five cases (80%; Table 2). Case 1 presented bladder capacity promotion and VUR alleviation on VCUG 18 months and 32 months after surgery, respectively (Fig. 4).

4. Discussion

BMLUS are rare and complicated challenges in the clinic. Current options for managing BMLUS represent various limitations. Endoscopic dilation combined with internal stenting can be the first step in treating, while surgical repair remains the preferred treatment when catheterization fails [1,7,8]. IUR is optional in managing various complicated bilateral long-segment ureteral strictures, but the incidence of complications, such as metabolic disorder, pyelonephritis, bowel obstruction, and fistula, is considerable [9—11]. Depending on the location and length of the ureteral strictures, combining different kinds of autografts (*e.g.*, appendiceal onlay graft, buccal mucosa, and lingual mucosa) with contralateral ureterovesical reimplantation with or without a Boari flap is technically feasible for the one-stage repairment of BMLUS. However, these complex methods make a high technical demand on the surgeon. Therefore, a feasible and effective surgical technique with less morbidity of complications is still needed.

The Boari flap is a viable and frequently performed procedure to repair mid-ureteral strictures when ureteral reimplantation and psoas hitch cannot cover the ureteral defects without tension [10,12,13]. With good protection of the blood supply, a normal capacity bladder can provide abundant materials for ureteral reconstruction, even for repairing a full-length ureter [14]. Based on these characteristics, the BBFUNC is designed to manage BMLUS in a one-stage procedure. Compared to the other surgical techniques mentioned above, BBFUNC has several potential advantages. First, this surgery obviates the need for IUR, which eliminates the risk of intestinal complications, including systemic acidosis and metabolic disorder, and makes it appropriate for patients who cannot be treated with IUR because of renal insufficiency. Second, the technique does not require additional autografts, thus avoiding donor-site injury and oral complications. Third, the operation does not require complete dissection of the entire bilateral ureteral stenotic segments or intraoperative

Table 2 Perioperative and follow-up data.

Perioperative and follow-up results	Case 1	Case 2	Case 3	Case 4	Case 5	Median (range)
Procedure	L-BBFUNC	RA-BBFUNC	L-BBFUNC	RA-BBFUNC	L-BBFUNC	–
Operative time, min	237	210	294	203	230	230 (203–294)
Flap length, cm						
Left	5.2	8.3	4.3	6.2	10.0	6.2 (4.3–10.0)
Right	4.7	9.8	5.5	5.5	10.5	5.5 (4.7–10.5)
Estimated blood loss, mL	40	150	110	80	50	80 (40–150)
Intraoperative complication	None	None	None	None	None	–
Postoperative hospitalization, day	7	6	6	6	7	6 (6–7)
Postoperative hydronephrosis						
Left	Grade 0	Grade 0	Grade 1	Grade 1	Grade 2	–
Right	Grade 0	Grade 1	Grade 2	Grade 1	Grade 2	–
Postoperative SRF, mL/min						
Left	30.2	45.4	12.9	49.6	68.4	45.4 (12.9–68.4)
Right	49.5	23.1	82.1	42.9	59.8	49.5 (23.1–82.1)
Symptoms after surgery[a]						
3 months	FPV	FPV and FU	FPV	FPV and FU	None	–
6 months	None	None	None	None	None	–
LUT function assessment after surgery[b]						
Post-void residual, mL	0	3	7	19	10	7 (0–19)
Q_{max}, mL/s	44.5	27.8	18.2	19.5	26.9	26.9 (18.2–44.5)
Maximal bladder capacity, mL	405	517	282	530	488	488 (282–530)
Follow-up time, month	45	18	17	17	16	17 (16–45)

L, laparoscopic; BBFUNC, bilateral Boari flap ureteroneocystostomy; RA, robot-assisted; SRF, split renal function; FPV, flank pain at voiding; FU, frequent urination; LUT, lower urinary tract; Q_{max}, maximum flow rate; –, not applicable.

[a] Symptoms of Cases 1–4 recorded in the table developed shortly after removing the nephrostomy tubes and recovered over the next 2–3 months. The flank pain usually occurred during the first-morning urination and was negative for the rest of the day.

[b] The postoperative data were obtained from the most recent review according to the follow-up plan.

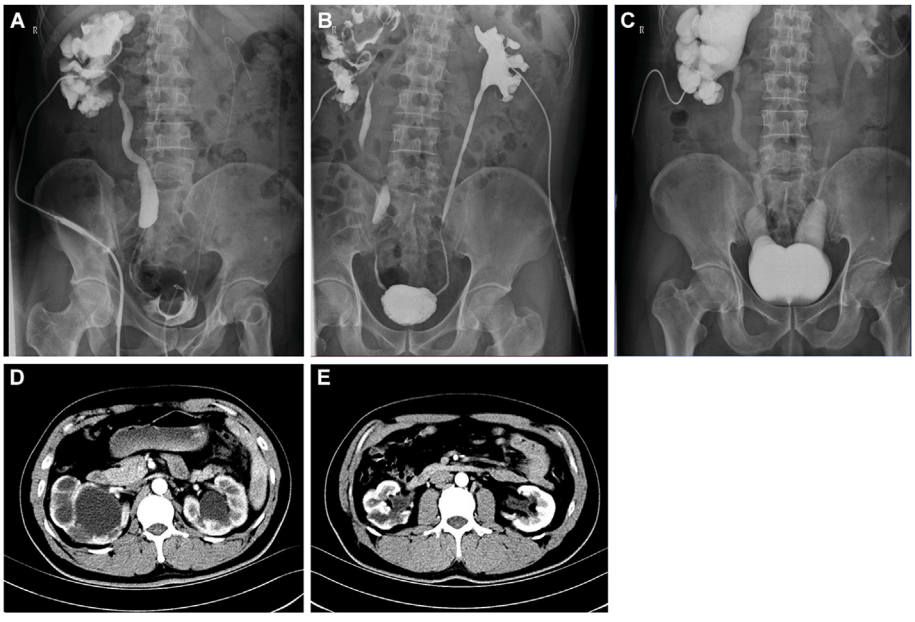

Figure 3 AU and CT urography of Case 4. (A) Right AU before surgery; (B) Left AU before surgery; (C) Bilateral AU 6 weeks after surgery; (D) Hydronephrosis before surgery; (E) Hydronephrosis significantly relieved 6 months after surgery. AU, antegrade urography.

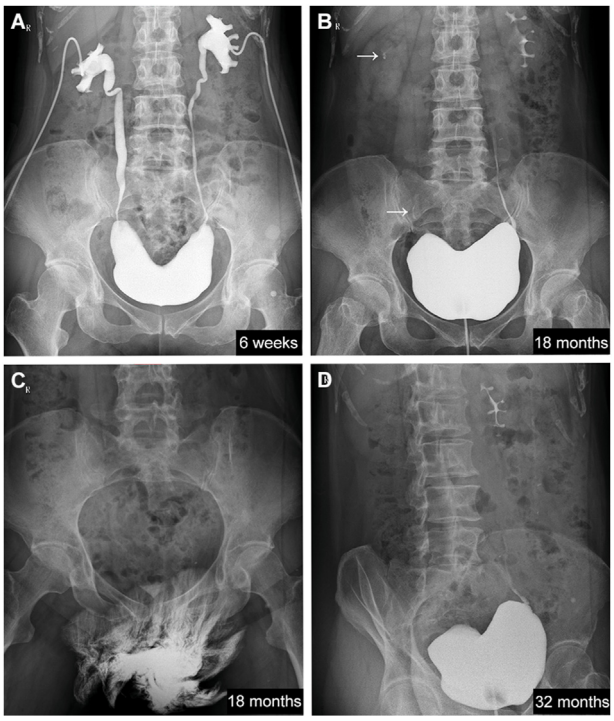

Figure 4 Voiding cystourethrogram of Case 1. (A) Six weeks after surgery—the bladder was approximately V-shaped, and the bilateral VUR was evident; (B) Eighteen months after surgery (storage period)—the bladder morphology was closer to normal, and the capacity had increased, but bilateral VUR still existed (the arrows indicated the VUR on the right side); (C) Eighteen months after surgery (urination period)—the contrast agent was fully discharged; (D) Thirty-two months after surgery (oblique right lateral view)—the VUR on the right side disappeared. VUR, vesicoureteral reflux.

change of the patient position, which greatly simplifies the procedure.

However, due to the rarity of BMLUS, only a few reports have been made about BBFUNC. In the 1960s, early studies sporadically reported the open surgery of BBFUNC and preliminarily showed the feasibility and effectiveness of the operation [15,16]. In 2018, Sagalovich et al. [17] first disclosed a video of a minimally invasive BBFUNC operation. They successfully performed RA-BBFUNC on an 82-year-old female and achieved satisfactory short-term results. These reports have yet to describe the technical details of BBFUNC, and the number of cases is very limited, especially for the minimally invasive procedure.

Our study first reports the minimally invasive BBFUNC in detail and presents close to 1-year follow-up data. The outcomes are encouraging. No case underwent intraoperative complications or symptoms of recurrent obstruction after removing the ureteral stents and nephrostomy tubes. The postoperative imaging tests exhibited good patency of the ureteral reconstruction segments, and the hydronephrosis in all patients was alleviated.

Despite the large amount of the bladder flap used in the procedure, the postoperative LUT function assessment hardly revealed any post-void residual or a normal maximum flow rate in all cases. Four of the five patients had a normal maximal bladder capacity after surgery (Table 2). In addition, the bladder showed a great compensatory capacity during the follow-up. Cases 2 and 4 reported frequent urination shortly after removing the nephrostomy tubes, while the symptom improved significantly 2 months later. The VCUG of Case 1 at 18 months and 32 months after surgery revealed the bladder volume increase and morphologic change (Fig. 4). These results suggest that minimally invasive BBFUNC is a feasible and valuable alternative in managing BMLUS, and the impact on LUT function is limited.

Sufficient blood supply is the prerequisite for the survival of bladder flaps. Unlike Sagalovich et al. [17], we incised the bladder from the middle of the anterior surface. The bilateral Bladder flaps were obtained respectively based on the actual length of ureteral defects with a base width of more than 4 cm and length-width ratio of less than 2:1, which could better preserve the blood supply and facilitate the flaps fashioned for different conditions. To prevent anastomotic stricture, tension-free interrupted sutures are necessary when anastomosing the Boari flap with a normal distal ureter. Identifying the diseased ureters is another challenge during operation. To ensure the tension-free anastomosis of the bladder flap and ureter, we first assessed the bladder capacity and morphology by preoperative VCUG. Insufficient bladder capacity is one of the contraindications for the surgery. Second, accurate localization and identifying the stenotic segments help us preserve the healthy ureter to the maximum extent. Third, fully mobilization of the bladder and dissecting the peritoneum and bilateral bladder pedicle can provide abundant materials for bilateral reconstruction. Last but not least, fixing the flaps onto the psoas tendons can also reduce the tension of anastomosis. As mentioned above, we prefer temporarily clamping the bilateral nephrostomy tubes or using methylene blue to help identify the segment of the proximal stenotic ureter. A 10 Fr catheter was also used to detect the patency of the proximal ureteral stump after the ureter was transected. Intraurethral injection of indocyanine green and visualization under near-infrared fluorescence is another practical way to locate ureteral stricture intraoperatively [18].

Considering the risk of stricture recurrence, we did not adopt anti-reflux measures in the procedure. As a result, four cases (4/5) reported slight flank pain during the first-morning urination 3 months after surgery. However, none of the patients complained that the symptom had a noticeable impact on their daily lives, and the flank pain got even milder 6 months after surgery. The long-term cystography of Case 1 also confirmed the alleviation of VUR (Fig. 4).

Our study has a few limitations: the small sample size, the short follow-up period, and retrospective nature of the present analysis. The rarity of patients with BMLUS increased the difficulty of obtaining eligible cases. Therefore, further studies with large samples, multiple centers, and longer follow-up periods are still necessary. To better observe the perioperative recovery, the patients were not recommended for discharge until the perivesical drainage tube and catheter were removed. Given the encouraging outcomes and experience of the present study, we will reduce postoperative hospitalization and remove the catheter and nephrostomy tubes early after surgery in future practice. Moreover, due to the small sample, our

study did not conduct a comparative analysis between the RA-BBFUNC and L-BBFUNC techniques. A comparation study between robotic-assisted, laparoscopic, and the open manner of BBFUNC is also the direction of our further research.

5. Conclusion

The present study demonstrates the feasibility and safety of minimally invasive BBFUNC in treating BMLUS, and the impact on LUT function is limited. Although further studies are needed, this technique is a valuable alternative to managing BMLUS.

Author contributions

Study concept and design: Bing Li, Xingyuan Xiao.
Data acquisition: Shuaishuai Chai, Hao Zhang.
Data analysis: Gong Cheng, Jiawei Chen, Xincheng Gao, Yuancheng Zhou.
Drafting of manuscript: Shuaishuai Chai, Hao Zhang.
Critical revision of the manuscript: Bing Li, Xingyuan Xiao.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgements

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