Initial Experience with the Comprehensive Modified Laparoscopic Pyeloplasty Technique Based on Membrane Anatomy for Treating Ureteropelvic Junction Obstruction

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Abstract

Objective: The aim of the objective was to present our initial experience and evaluate the feasibility of the novel comprehensive modified laparoscopic pyeloplasty (CMLP) technique based on membrane anatomy. ***Materials and Methods:*** Forty-eight patients underwent CMLP from February 2016 to October 2020. CMLP involves the following: dissection of the ureter was based on the fascia or fusion fascia formed by embryonic development. The ureter was separated from the ureteral sheath, and the pelvis and ureter were incised with incomplete amputation. The first stitch was placed between the lower point of the spatulated ureter and the lowest corner of the renal pelvis to ensure correct orientation of the anastomosis; anastomosis of the renal pelvis and ureter was performed using the touchless technique. ***Results:*** All CMLPs were completed successfully without conversion. The mean overall operating time was 230.96 min. The median estimated blood loss was 50.00 (interquartile range 20.00–57.50) mL. The average postoperative hospital stay was 9.31 days. The average follow-up time was 24.73 months. No major complications occurred. In 1 case, revision laparoscopic pyeloplasty was performed, but the obstruction persisted after double J stent removal, so ultimately, the double J stent required regular replacement. Another asymptomatic patient with hydronephrosis experienced failed treatment and is still under follow-up. The overall success rate was 95.83% (46/48). The success rate in patients with recurrent ureteropelvic junction obstruction (UPJO) was 87.5% (7/8). ***Conclusions:*** CMLP is a practical and effective treatment option for UPJO with a high success rate. An advantage of CMLP is the clear surgical field.

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Introduction

Ureteropelvic junction obstruction (UPJO) has various etiologies and results in decreased urine flow from the renal pelvis to the ureter [1, 2]. In the past, open pyeloplasty (OP) was the gold standard treatment for UPJO. Since Schuessler first reported laparoscopic pyeloplasty (LP) in 1993, it has become the first choice treatment for UPJO because of its minimal invasiveness. The success

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rate is >90% in both children and adults [3]. The failure rate of OP and LP is approximately 2.5%–10%. Some studies have shown that approximately 11.4% of patients who underwent pyeloplasty for the first time eventually need surgical reintervention [4]. The most common causes of recurrent UPJO are anastomotic stricture and fibrous scar formation, which are related to the separation, cutting, and suturing of the renal pelvis and ureteral junction. In addition, traditional LP may be complicated by an unclear surgical field. Membrane anatomy is a surgical technique that uses the "Holy Plane" for the anatomical approach, the "Holy Plane" being an avascular interface that originates from the mesentery or fused fascia that is formed during embryonic development and contains loose connective tissue [5, 6]. The organs in the urinary system are surrounded and separated by the space between the fascia and fusion fascia formed during embryonic development. Compared with surgical techniques based on traditional anatomy, surgical techniques based on "membrane anatomy" enable maintenance of a relatively clear surgical field, which is very important for the surgical process. We have adopted the latest concepts of membrane anatomy, extrathecal free ureters, incomplete amputation and cutting of the ureteropelvic junction (UPJ), and anastomosis of the renal pelvis and ureter without the clamp. In this study, we share our experience with comprehensive modified laparoscopic pyeloplasty (CMLP) and its outcomes in 48 patients who underwent CMLP.

Material and Methods

We retrospectively analyzed the clinical data of 48 patients with UPJO who underwent CMLP by the same surgeon at 2 different institutions (The First Affiliated Hospital of Jinan University and The First People's Hospital of Zhaoqing) from February 2016 to October 2020. UPJO was diagnosed based on clinical symptoms, physical examination, and imaging, including abdominal ultrasonography, computed tomography (CT), CT urography (CTU), and intravenous urography. Elective criteria were recurrent urinary tract infections or flank pain, renal parenchymal atrophy, and impaired split renal function below 40% [7]. Exclusion criteria for these preliminary series were pelvic kidney and horseshoe kidney; patients with extensive or multifocal strictures (>6 cm) were also excluded, and ileal ureter replacement was implemented for them in our center.

All data, including demographic data (age and gender), symptoms present before surgery, intraoperative blood loss, open conversion rate, postoperative complications, postoperative drainage fluid, hospitalization stay, follow-up time, and follow-up results, were collected retrospectively to evaluate the safety and efficacy of this modified technique. The Foley catheter or DJ stent was removed 1 week or 1–2 months after surgery, respectively. During
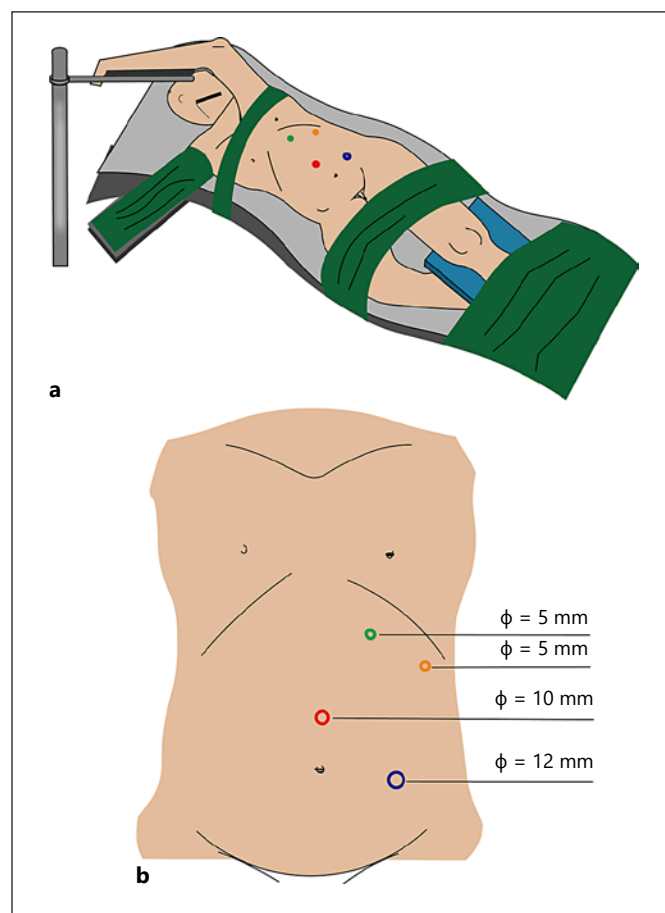

Fig. 1. Position (**a**) and port placement (**b**) in comprehensive modified laparoscopic pyeloplasty.

postoperative follow-up, telephone follow-up, B-ultrasound CTU, and diuretic renal dynamic imaging were used as follow-up tools. B-ultrasound was recommended for all patients because not all patients could afford the cost of CT or diuretic renal dynamic imaging because of economic factors and Chinese health policy. Success was defined as the alleviation of subjective symptoms and the improvement of hydronephrosis [8]. This study was approved by the Ethics Committee of Jinan University, and all patients' guardians signed an informed consent form before the operation.

Statistical analysis was performed with SPSS (version 25.0) software. The main data are reported as arithmetic mean values and standard deviations, or as medians and interquartile ranges (IQRs) if non-normally distributed. Student's t test was performed to evaluate significant differences. Differences were considered to be statistically significant when the p values were <0.05.

Surgical Technique

After general anesthesia was induced, catheters were inserted. The patients were positioned in the lateral flank position with a 60°–70° inclination (the left side, for instance; Fig. 1a). A small incision (10 mm in diameter) was made 30 mm along the upper edge of the umbilicus, and a Veress needle was inserted to establish
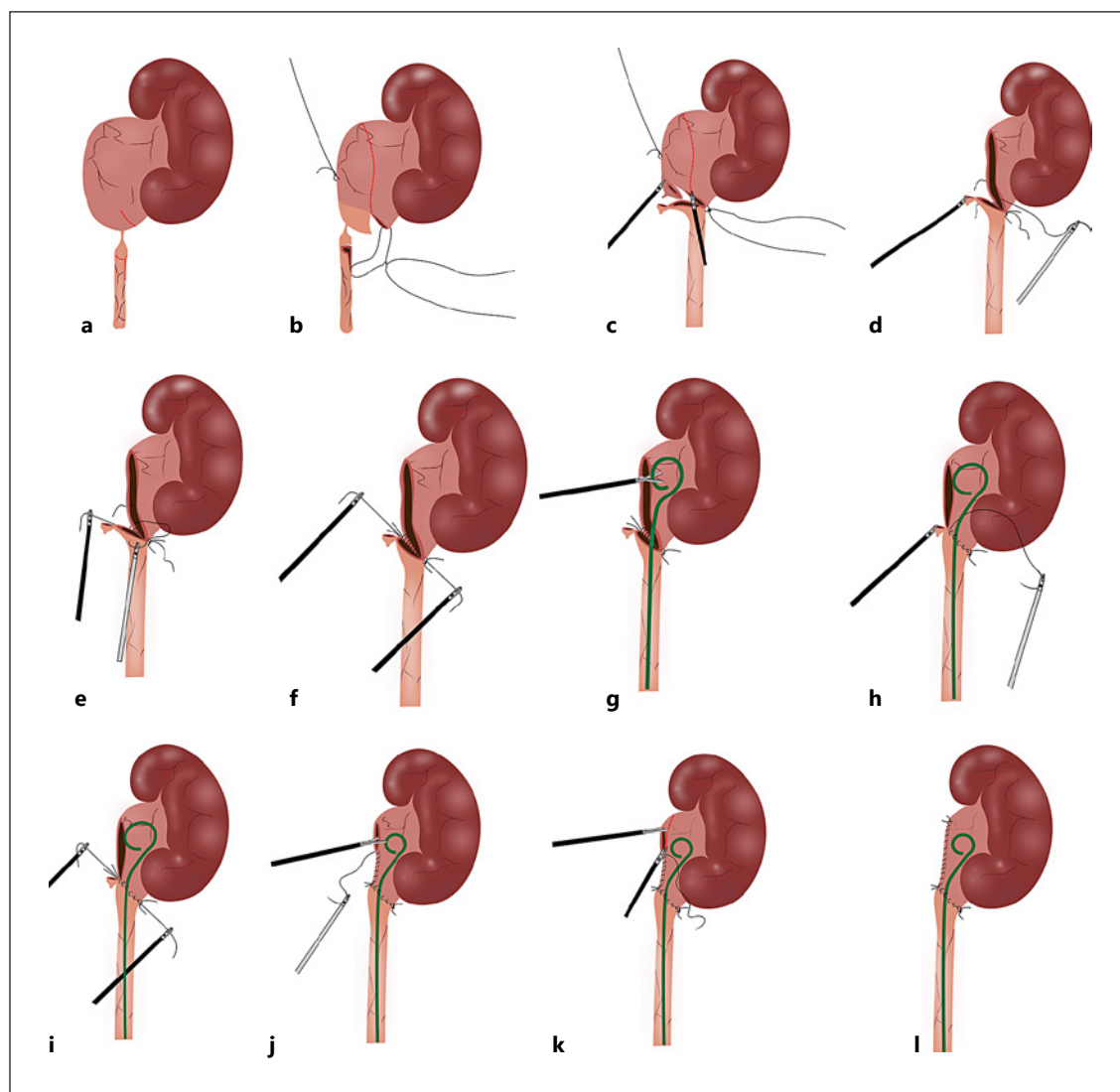
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Fig. 2. CMLP. UPJO, schematic diagram of trimming of the UPJ and renal pelvis (**a**); the first stitch was placed between the lower point of the spatulated ureter and the lowest corner of the renal pelvis (**b**); trimming of the renal pelvis (**c**); the posterior wall of the anastomosis formed using the touchless technique (**d**, **e**); place-ment of a ureteral stent (**f**); the anterior wall of the anastomosis formed using the touchless technique (**g**, **h**); trimming of the re-dundant renal pelvis (**i**); CMLP was completed (**j**, **k**). CMLP, com-prehensive modified laparoscopic pyeloplasty; UPJO, ureteropel-vic junction obstruction; UPJ, ureteropelvic junction.

pneumoperitoneum. A 10-mm trocar was placed along the Veress needle as a camera port. During the surgery, the pneumoperito-neum pressure was maintained at 12–14 mm Hg (1 mm Hg = 0.133 kPa). The main 2 operative trocars (5 mm and 12 mm) were in-serted below the rib edge at the midclavicular line and at the inter-section of the umbilical level and the anterior axillary line, respec-tively. Additionally, when the right side was affected, a 5-mm tro-car was placed just below the xiphoid process for liver retraction (Fig. 1b). The transperitoneal approach is preferred for patients with severe hydronephrosis or previous retroperitoneal surgery, while the retroperitoneal approach is used for patients with intra-renal pelvis or mild hydronephrosis.

Transperitoneal Approach

On the left, the planes were dissociated between the descending colon, the splenic flexure of the colon, the tail of the pancreas, and the front of the prerenal fusion fascia. On the right, by carefully dissecting between the back of the colon's mesenteric fascia and the front of the renal fascia, the colonic fusion fascia on the right side was incised. The ascending colon and the hepatic flexure of the colon were separated from the prerenal fusion fascia. The sep-aration of the horizontal part of the duodenum began in front of the inferior vena cava, and the ureter was exposed at the medial lower pole of the kidney. Essential surgical steps in CMLP include the mobilization of the ureter based on membrane anatomy for approximately 8–10 cm to achieve a sufficient length. The ureter

was separated from the ureteral sheath and dissected up to the renal pelvis, with sufficient vascular preservation and careful recognition of the ureter and the obstructed area. If adjacent tissue adhesion was encountered, blunt and sharp dissection of dense adhesions was meticulously carried out.

Depending on the shape of the renal pelvis and degree of hydronephrosis, the renal pelvis was cut approximately 2–4 cm obliquely. The ureter below the level of the UPJ was cut with a T incision, which combined a partial transverse incision and a 2-cm longitudinal incision. However, the ureter and pelvis were still partially connected [9]. The first stitch was placed between the lowest corner of the renal pelvis and the lowest point of the spatulated ureter (Fig. 2a, b). The stenotic segment of the UPJ was dismembered in the middle as the clamp area. The grasping plier was used to clamp the UPJ and pull it slightly outward to allow distension of the renal pelvis to assist with dissection. The renal pelvis was cut obliquely to an extent equal to the size of ureteral spatulation (Fig. 2c). The posterior wall of the anastomosis was closed by continuous suturing with the help of the traction line or UPJ for the touchless technique, and a 5–0 Vicryl suture was used for full-thickness continuous suturing of the posterior wall (Fig. 2d, e). Then, 1 end of the ureteral stent tube was placed in the distal ureter. At the same time, the other end was placed in the renal pelvis (Fig. 2f), and the anterior wall of the anastomosis was closed by continuous suturing with the help of the traction line for the touchless technique (Fig. 2g, h). A part of the redundant renal pelvis was excised, while the margin was continuously sutured (Fig. 2i, j). If a crossing vessel was encountered, CMLP with transposition of the reanastomosed ureter ventral to the vessels was performed [10]. Then, CMLP was completed (Fig. 2k). After the surgical bed was irrigated with normal saline, a 22 F drain was placed through the trocar into the surgical bed. The drain was removed when drainage was reduced to <10 mL/day.

Retroperitoneal Approach
Patients were placed in a lateral position with a raised waist bridge, and the conventional 3- or 4-hole method was used. The extraperitoneal fat layer was cleared, while the lateroconal fascia, renal fascia, and perirenal fat capsule were cut obliquely. The posterior margin of the kidney was dissociated along the plane of the renal fat capsule and the renal capsule, and the ureter and renal pelvis were exposed below the kidney.

Results

In total, 48 patients underwent CMLP at 2 urology centers during the study period from February 2016 to October 2020. The left side was affected in 30 patients (62.5%), and the right side was affected in 18 patients (37.5%). The mean age of the patients was 29.7 (range, 0.25–73) years. Thirty-one patients complained of frequent and intolerable flank pain, whereas 17 were asymptomatic. Before hospitalization, 10 patients had renal stones, 3 patients underwent ureteroscopic lithotripsy, 5 patients underwent percutaneous nephrolithotomy, and 8 patients had recurrent UPJO after failed open or lapa-

roscopic repair. The transabdominal approach was used in 34 patients, while the retroperitoneal approach was used in 14 patients. The mean overall operating time was 230.96 min. The mean overall operation time was slightly longer with the transperitoneal approach than with the retroperitoneal approach (236.85 min vs. 216.64 min, respectively; $p = 0.430$). The median estimated blood loss was 50.00 mL (IQR 20.00–57.50), and no cases required intraoperative or postoperative blood transfusions. Crossing vessels were noted in 8.33% of the patients (4/48). No open conversion or major complications occurred during the intraoperative periods. The average surgical incision length was 1.66 cm. The average postoperative hospital stay was 9.31 days. The median postoperative drainage volume was 105.50 mL (IQR 50.25–181.00). Major postoperative complications occurred in 7 patients (14.58%), including urine leakage in 3 cases, urinary tract infection in 1 case, incomplete intestinal obstruction in 1 case, parapelvic hematoma in 1 case, and short-term stricture of the anastomosis in 1 case. Six of them were treated conservatively, and 1 case required revision LP. The obstruction persisted after double J stent removal, and ultimately, the double J stent required regular replacement. All patients were followed up, and the average follow-up time was 24.73 months. In the flank pain group, 30 patients (96.77%) had subjective pain relief. According to the imaging results, an improvement in hydronephrosis was identified in 46 patients (95.83%), but in 1 patient (asymptomatic group), B-ultrasonography showed a clear increase in pelvic dilatation. The success rate in patients who had recurrent UPJO after prior failed OP or LP was 87.5% (7/8). The overall success rate was 95.83% (46/48) with the combination of these 2 criteria (Table 1).

Discussion

Historically, OP was the gold standard for the management of UPJO [11]. Nevertheless, in the minimally invasive era, LP has become an alternative for UPJO management. The main goals of surgery are to remove the lesion site, relieve symptoms, and maintain or improve renal function [2, 12]. In reconstruction of the upper urinary tract, important considerations include minimizing ureteral manipulation and preserving ureteral blood supply [13]. LP of the ureter is a challenging part of upper urinary tract reconstruction, even for an experienced surgeon. At present, minimally invasive LP is mostly used to address cosmetic results [14, 15], but we pay more atten-

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Table 1. Demographic, perioperative, and follow-up details of the included patients

	CMLP	p value
Patients, *n*	48	
Gender (male/female)	31/17	
Mean age, years, mean±SD (range)	29.73±16.92	
Side (L/R), *n*	30/18	
Symptoms, *n*		
Flank pain	31	
Asymptomatic	17	
Presentation		
Renal stone, *n*	10	
Recurrent UPJO after failed open or laparoscopic repair, *n*	8	
Ureteroscopic lithotripsy, *n*	3	
Percutaneous nephrolithotomy, *n*	5	
Surgical approach (TP/RP)	34/14	
Overall operative time, min, mean±SD (range)	230.96±79.69	0.430
TP	236.85±77.27	
RP	216.64±86.57	
Estimated blood loss, mL, median days (IQR)	50.00 (20.00–57.50)	
Crossing vessel, *n* (%)	4	
Intraoperative complications, *n*	0	
Conversion rate, %	0	
Surgical incision length, cm, mean±SD (range)	1.66±0.52	
Hospital stay, days, mean±SD (range)	9.31±4.56	
Postoperative drainage, mL, median days (IQR)	105.50 (50.25–181.00)	
Postoperative complications, *n*	7	
Urine leakage, *n*	3	
UTI, *n*	1	
Incomplete intestinal obstruction, *n*	1	
Parapelvic hematoma, *n*	1	
Stricture of short-term anastomosis, *n*	1	
Follow-up time, months, mean±SD (range)	24.73±14.90	
Patients followed up, *n*	48	
Patients lost to follow-up, *n*	0	
After operation, *n*		
Flank pain group		
Complete relief of pain, *n*	30	
No relief of flank pain, *n*	1	
Asymptomatic group		
Radiographic relief, *n*	16	
Success rate, *n* (%)	46/48 (95.83)	

n, number; L, left; R, right; TP, transperitoneal approach; RP, retroperitoneal approach; UTI, urinary tract infection; CMLP, comprehensive modified laparoscopic pyeloplasty; UPJO, ureteropelvic junction obstruction; IQR, interquartile range.

tion to protecting the blood supply of the ureter and avoiding side injuries. The new approach based on membrane anatomy not only enables a clear field of view but also minimizes tissue trauma and maximizes functional preservation.

What is "membrane anatomy"? The process of gastrulation gives rise to the formation of trilaminar embryos in humans during the third week of pregnancy, and the urogenital system originates from the intermediary mesoderm [16]. The urinary system grows and develops along the axis of the mesoderm-nephrogenic cord-metanephros kidney and ureter [17]. The renal primordium originates from the metanephros, and the renal primordium with its surrounding fasciae forms the renal capsule, which rises to the retroperitoneal space. The retroperitoneal space, located between the posterior parietal perito-
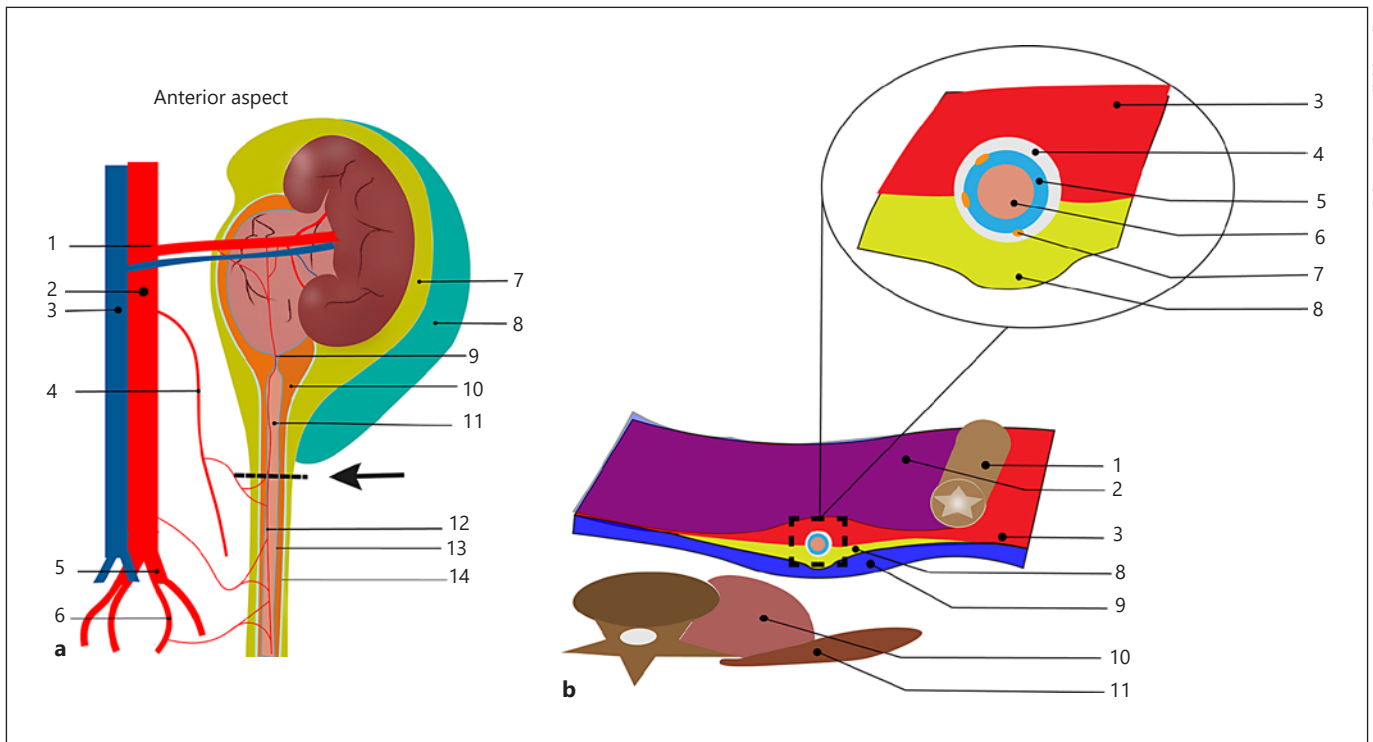
Fig. 3. Schematic diagram of the concept of membrane anatomy. **a** Diagram of a coronal cross section through the anatomical structure of the urinary system and the ureteric sheath (left kidney). 1, Renal arteries; 2, aorta; 3, vena cava; 4, ovarian/testicular arteries; 5, common iliac arteries; 6, internal iliac artery; 7, perirenal fat; 8, pararenal fat; 9, UPJ; 10, renal hilar fat; 11, ureter; 12, ureteral feeding vessel; 13, ureteric sheath. **b** Diagram of an axial cross section of the embryonic fascia or fusion fascia that surrounds and separates the ureter. Transverse sections are indicated by an arrow in **a**. 1, descending colon; 2, prerenal fusion fascia; 3, parietal peritoneum; 4, transversalis fascia; 5, posterior renal fascia; 6, ureter; 7, ureteric sheath; 8, psoas; 9, quadratus lumborum. UPJ, ureteropelvic junction.

neum and transversalis fascia, begins from the diaphragm cranially and ends in the pelvis caudally [18, 19]. The perirenal space consists of the anterior renal fascia and the posterior renal fascia. The perirenal spaces contain the kidneys, adrenal glands, and ureters. The ascending colon, descending colon, duodenum, and pancreas are located in front of the prerenal fascia. In addition, a thin fibrous connective tissue sheath covers the ureter, periureteral fat, and ureteral feeding vessels (Fig. 3a). The anatomical structure of the fascia around the ureter from front to back is as follows: parietal peritoneum, prerenal fusion fascia, posterior renal fascia, and transversalis fascia (Fig. 3b). Therefore, different organs are separated by different fascias, and there is a potential avascular plane between the fascias. For example, the avascular plane referred to as the fusion fascia of Toldt is well-known. In general, traditional techniques have mainly focused on the blunt or sharp separation of tissue, but the key feature of membrane anatomy is more elaborate and maintains a relatively clear surgical field, which plays an equally important role and does not receive enough attention. In our technique, the dissection of the ureter is based on the fascia or fusion fascia formed by embryonic development. In this way, the operation is more elaborate and causes less tissue damage, and the biggest advantage is that a clear field of vision is obtained.

We also noticed that the clamp problem during the anastomosis process in traditional LP can also cause anastomotic ischemia, which would lead to anastomotic stricture. To prevent anastomotic ischemia and anastomotic obstruction and thereby improve the success rate, CMLP takes into account the following 2 considerations: (1) the first stitch is placed between the lower point of the spatulated ureter and the lowest corner of the renal pelvis. The critical step during the first stitches is that thinner threads are chosen as much as possible. We sutured 5–0 Vicryl sutures to reduce the risk of inflammation. In contrast, Radford et al. [20] used a V-Loc suture, which led to sig-

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nificant hydronephrosis or revision pyeloplasty. (2) During separation, cutting, and anastomosis, the renal pelvis and ureter were not grasped or touched with instruments. At the same time, we also followed the basic principles of ureteral reconstruction (tension-free and watertight mucosa-to-mucosa anastomosis with absorbable sutures) [21]. We have presented our experience using these modifications for treating UPJO in this study. Compared with previous reports of LP for UPJO, CMLP based on membrane anatomy has a superior clear surgical field. In terms of the success rate, we achieved a satisfying overall success rate (95.83%) compared with the published reports on LP (92–98.44%) [22–24]. The average postoperative hospital stay was 9.31 days, which was high compared to that reported in the existing literature on LP (4.2–7.48 days) [25, 26]. The reasons for this discrepancy may be that the patient was not discharged from the hospital until the wound healed favorably and the sutures were removed, increasing the average postoperative hospital stay. The operation time of most LPs is <200 min [27, 28], and our average operation time was 230 min, which may be because our technique involved an elaborate and precise operation. One patient with a scar constitution had urine leakage after the operation. She was treated conservatively and still had frequent and intolerable flank pain after the stent was removed. Further, ureteroscopy showed peristaltic waves in the middle and lower ureter, but no peristaltic waves were seen in the upper ureter. Her flank pain symptoms were relieved after reimplantation of the stent, and further, CTU showed no obstruction after 3 months. She had stable renal function, and no recurrent ureteral stricture was observed at the end of the follow-up. Overall, our initial experience is encouraging. We hope that LP based on the concept of membrane anatomy can provide guidance for ureter dissection.

A few limitations of this study are worth considering. First, due to its retrospective nature, selection bias is inevitable. Additionally, anatomical planes are often distorted in previously operated cases, and the concept of membranous anatomy may not be valid in these cases. This is a pilot study; therefore, prospective randomized controlled studies in multiple centers with larger samples and longer follow-ups are needed in the future.

Conclusion

CMLP is a practical and effective treatment option for UPJO with a high success rate. An advantage of CMLP is the clear surgical field.

Statement of Ethics

This study was approved by the Ethics Committee of Jinan University (KY-2021-077). Written informed consent was obtained from each patient.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

Author Contributions

G.W. involved in manuscript writing, acquisition of data, analysis, and interpretation of the data. H.L. performed manuscript writing and supervision. P.Z., D.C., and Z.Z. conceived assistance with data collection. Z.G., Y.Z., and L.X. reviewed the manuscript. C.L. involved in project development, management, operations, and supervision. All authors agree to all aspects of the work.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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