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Robotic Surgery for Ureteral Stricture in Adult Duplex System: Techniques and midterm outcomes

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Abstract

We describe the surgical techniques and midterm outcomes of two robot-assisted approaches for adult duplex collecting system (DCS) with ureteral strictures. Between August 2023 and January 2026, 51 adults with DCS and ureteral strictures underwent robot-assisted surgery, assigned to heminephrectomy (resection, n = 23) or upper urinary tract reconstruction (reconstruction, n = 28). Primary outcomes were the 6-month change in affected-side estimated glomerular filtration rate (eGFR) and overall success; secondary outcomes included operative time, estimated blood loss, transfusion, hospital stay, and Clavien-Dindo complications. In the resection group, affected-side eGFR increased from 41.2 to 47.6 mL/min with a 91.3% success rate, median operative time, blood loss, and hospitalization were 158 (135–195) min, 100 (50–100) mL, and 5 (4–7) days, and 9 and 3 patients had grade I-II and III-IV complications, respectively. In the reconstruction group, affected-side eGFR increased from 42.1 to 52.9 mL/min with a 100% success rate, median operative time, blood loss, and hospitalization were 120 (101–145) min, 20 (20–20) mL, and 4 (4–4) days, and 1 patient had a grade I-II complication. Both approaches were safe and effective, significantly improving affected-side renal function and symptoms. Reconstruction tended to yield better symptom control, greater renal functional recovery, and more advantageous perioperative profiles.

1.Introduction

Duplex kidney with ureteral duplication encompasses a heterogeneous spectrum of congenital anomalies, including non-functional upper moieties, proximal ureteral obstruction, distal ureteral obstruction, and vesicoureteral reflux, each with distinct pathophysiologies and therapeutic strategies[1–3]. Given this heterogeneity, direct comparisons across different entities are inherently challenging. Therefore, to ensure a homogeneous cohort and a valid comparison, this study specifically focused on adult patients with symptomatic duplex collecting system (DCS) complicated by obstructive ureter or severe hydronephrosis with preserved parenchyma in the affected moiety, for whom both robotic-assisted laparoscopic heminephrectomy and upper urinary tract reconstruction are theoretically viable therapeutic options.

With the advancement of minimally invasive robotic platforms, upper urinary tract reconstruction has gained increasing attention as a nephron-sparing alternative. Unlike heminephrectomy, which ablates the diseased unit, reconstruction aims to relieve obstruction and restore antegrade flow while preserving functional renal parenchyma[4]. Although robot-assisted ureteroureterostomy has demonstrated feasibility and safety in patients with duplicated ureters complicated by obstruction, high-quality comparative evidence in adults remains scarce[5, 6].

The inherent anatomical variability of the DCS demands individualized treatment and presents unique surgical challenges. Herein, we describe our experience with robot-assisted heminephrectomy and upper urinary tract reconstruction for adult patients with DCS and ureteral strictures, and evaluate their

perioperative and midterm functional outcomes. This study aims to offer standardized approaches and a clinical reference for the optimal application of these techniques.

2.Methods

2.1 Study Design

This study is a retrospective observational cohort study enrolling patients diagnosed with duplex kidney anomalies and completing standardized preoperative evaluation at the Department of Urology, Chinese People's Liberation Army General Hospital between August 2023 and January 2026. All patients underwent contrast-enhanced CT of the urinary tract with three-dimensional reconstruction, retrograde and antegrade pyeloureteropyelography,and ^{99m}Tc-DTPA renal scintigraphy to assess split renal function. Routine blood tests, urinalysis, and assessment of hepatic and renal function were also performed. The same ^{99m}Tc-DTPA renal scintigraphy was repeated at 6 months postoperatively to evaluate changes in split renal function. According to the surgical approach, 23 patients underwent robot-assisted heminephrectomy and 28 underwent robot-assisted upper urinary tract reconstruction. Among the 28 patients in the reconstruction group, 11 underwent ureteroureterostomy and 17 underwent ureteroneocystostomy. Given the inherent differences in patient selection between the two surgical approaches, direct statistical comparisons between groups were not performed. Instead, perioperative and functional outcomes are presented separately for each cohort, with descriptive comparisons provided for exploratory purposes. This study adhered to the ethical principles set forth in the Declaration of Helsinki. The study protocol and written informed consent were approved by the ethics committee of the Third Medical Center, Chinese PLA General Hospital (approval No. S-2024-208-02).

2.2 Patient Selection

Inclusion criteria were: (1) age ≥ 18 years; (2) unilateral DCS with ureteral stricture; (3) preserved function in the affected moiety; (4) congenital anomaly; (5) significant symptoms or severe hydronephrosis on imaging; and (6) complete perioperative and follow-up data.

Exclusion criteria were: (1) bilateral DCS; (2) previous ipsilateral upper tract surgery or nephrectomy; (3) concurrent malignancy or hematological disease; (4) other severe urinary anomalies; (5) history of abdominal radiation or tuberculosis; (6) ureteral polyps; and (7) incomplete perioperative or follow-up data.

2.3 Surgical Decision-Making and Operative Approach

All nuclear medicine images were independently interpreted by three radiologists, with a third adjudicating discrepancies. Surgical plans were determined jointly by two urologists based on preoperative findings, and all procedures were performed by one experienced surgeon. Cases from the surgeon's learning curve were excluded.

Surgical approach selection was guided by each patient's preoperative symptoms, anatomical characteristics, and the assessed preservation value of the duplex renal unit on the affected side. Heminephrectomy was selected when affected-side renal function was severely impaired, when recurrent infection or significant obstruction was present, and when the renal unit offered no viable preservation value (Fig. 1A). Upper urinary tract reconstruction was preferred when preservable affected-side renal function remained and the anatomy permitted reconstruction.

Reconstructive procedures included robot-assisted laparoscopic end-to-side ureteroureterostomy and ureteroneocystostomy. When the duplicated ureter converged with the normal ureter and the site of confluence was stenotic (incomplete duplex), end-to-side ureteroureterostomy was performed (Fig. 1B). When the duplicated ureter had an ectopic orifice or ureterovesical junction stricture (complete duplex), ureteroneocystostomy was employed (Fig. 1C). No renal parenchyma was excised during upper urinary tract reconstruction; the procedure was limited to anastomotic reconstruction alone.

2.4 Surgical Procedures

Preoperatively, a double-J ureteral stent was placed in the normal ureter under cystoscopic guidance to facilitate intraoperative identification and prevent injury to the normal ureter.

2.4.1 Heminephrectomy

Detailed surgical procedures are described in Supplementary Method. In brief, after identifying the duplex moiety as a cystic protrusion on the renal surface, dissection proceeded from the mid-kidney toward the renal hilum. The dilated duplicated ureter was identified between the lower renal pole and the psoas major muscle, then transected at the iliac vessel level using an endoscopic linear stapler. The renal artery was dissected, and any accessory artery supplying the duplex moiety was divided with Hem-o-lok clips while preserving blood supply to the remaining parenchyma. The boundary between the duplex moiety and normal parenchyma was identified, and parenchymal incision was made along this demarcation. The renal pelvis mucosa of the duplex moiety was completely dissected. When significant hemorrhage occurred during resection, temporary renal artery occlusion was used. The parenchymal defect was closed with a continuous barbed suture (Fig. 2A–D).

2.4.2 Ureteroureterostomy

The dilated renal pelvis and proximal ureter were fully mobilized as described above.

Detailed ureteroureterostomy procedures are described in Supplementary Method. In brief, the duplicated ureter was incised at the stenotic confluence with the normal ureter, and the stenotic segment was excised. After trimming the dilated renal pelvis, the duplicated ureter was spatulated longitudinally beyond the stricture. Using absorbable suture, the transected end of the duplicated ureter was anastomosed to the lateral wall of the normal ureter in a tension-free and non-twisted fashion, with the posterior wall sutured continuously. A double-J ureteral stent was placed in the duplicated ureter,

after which the anterior wall of the anastomosis was closed with interrupted absorbable sutures. The outflow tract opening was then closed continuously using absorbable suture (Fig. 2E–H).

2.4.3 Ureteroneocystostomy

Detailed ureteroneocystostomy procedures are described in Supplementary Method. In brief, the dilated duplicated ureter was carefully dissected on the surface of the common iliac artery. The peritoneum overlying the ureter was opened, and the middle and distal segments of the duplicated ureter were mobilized distally to the ureterovesical junction. The distal end of the ureter was secured with Hem-o-lok clips and divided.

After distending the bladder, the serosal, muscular, and mucosal layers were opened sequentially. The distal end of the duplicated ureter was longitudinally spatulated and sutured to the posterior bladder mucosa with a continuous absorbable suture. A double-J ureteral stent was placed, and the anterior wall of the anastomosis was closed with interrupted absorbable sutures. The bladder muscular and serosal layers were then closed in a tunneled fashion using absorbable suture (Fig. 2I–L).

2.5 Outcome Measures

Baseline data were collected from the institutional duplex kidney database. Preoperative and postoperative renal function was evaluated by estimated GFR (eGFR), which was derived from ^{99m}Tc-DTPA scintigraphy. Besides, eGFR normalized to standard body surface area was estimated using the Modification of Diet in Renal Disease (MDRD) formula[7]. Changes in eGFR from before to 1 day and 6 months after surgery were calculated. Severe hydronephrosis was defined per Yale criteria as calyceal distension with renal cortical thinning[8]. Surgical success was defined according to the following criteria: (1) absence of symptoms or symptom resolution; (2) no evidence of obstruction on postoperative imaging; and (3) stable or improved renal function[9]. Safety outcomes included operative time, estimated blood loss, renal artery clamping, transfusion, hospital stay, drain and catheter days, 30-day complications[10, 11].

2.6 Statistical Analysis

Statistical analysis was performed using SPSS 26.0. Given the non-comparative design of this study, formal inferential statistics between the resection and reconstruction groups were not performed. Normally distributed continuous variables are expressed as mean +/- standard deviation and compared between groups using the independent samples t-test. Non-normally distributed continuous variables are expressed as median (Q1, Q3) and compared using the Mann-Whitney U test. Categorical variables are expressed as frequency (%) and compared using the chi-square test or Fisher's exact test. Within-group preoperative-to-postoperative comparisons were performed using the paired t-test or Wilcoxon signed-rank test. All tests were two-tailed, with $P < 0.05$ considered statistically significant.

3.Results

3.1 Overall Surgical Outcomes: Symptom Relief and Renal Function Improvement

This study included 51 patients with duplex kidney who underwent robot-assisted laparoscopic surgery. All procedures were completed successfully, and no conversion to open surgery was required. In terms of symptomatic outcomes, the proportion of patients with subjective symptoms decreased significantly from 80.4% (41/51) preoperatively to 3.9% (2/51) postoperatively ($P < 0.001$), with an overall success rate of 96.1%. Regarding renal function, total renal functional indices remained stable at 6 months postoperatively compared with baseline: serum creatinine (68.7 vs 65.6 μmol/L, $P = 0.336$), total eGFR ($P = 0.132$), and eGFR/1.73 m^2 ($P = 0.144$), as shown in Table 1.

Table 1
Preoperative and 6-mo postoperative total and affected-side renal function

Variable	Preoperative (n = 51)	6-mo postoperative (n = 51)	Statistic	p value[a]
In the overall cohort (n = 51)				
Clinical symptoms, n (%)	41 (80.4)	2 (3.9)	-	< 0.001[b]
Severe hydronephrosis, n (%)	34 (66.7)	0	-	< 0.001[b]
Serum creatinine, μmol/L, mean (SD)	68.7 (16.5)	65.6 (15.5)	0.967	0.336
Total eGFR, mL/min, mean (SD)	103.1 (21.4)	110.1 (25.3)	1.518	0.132
Total eGFR, mL/min per 1.73 m², mean (SD)	101.7 (21.4)	108.3 (24.1)	1.473	0.144
Affected-to-contralateral renal dynamic imaging ratio, mean (SD)	0.39 (0.07)	0.43 (0.08)	2.536	0.013
Affected-side eGFR, mL/min, mean (SD)	41.7 (12.9)	50.5 (15.8)	3.093	0.003
Affected-side eGFR, mL/min per 1.73 m², mean (SD)	40.9 (11.9)	49.5 (14.2)	3.300	0.001
In the resection group (n = 23)				
Affected-side eGFR, mL/min, mean (SD)	41.2 (9.0)	47.6 (9.6)	1.342	0.024
Affected-side eGFR, mL/min per 1.73 m², mean (SD)	39.9 (7.8)	46.2 (8.0)	2.723	0.009
In the reconstruction group (n = 28)				
Affected-side eGFR, mL/min, mean (SD)	42.1 (15.6)	52.9 (19.3)	2.304	0.025
Affected-side eGFR, mL/min per 1.73 m², mean (SD)	41.7 (14.6)	52.2 (17.8)	2.425	0.019

eGFR, estimated glomerular filtration rate; SD, standard deviation.

[a] Except where otherwise noted, p values are for a t test for continuous data

[b] Fisher's exact test

By contrast, affected-side renal function improves significantly after surgery. The affected-to-contralateral renal dynamic imaging ratio improve in baseline was 0.04 (P = 0.013). Affected-side eGFR improve in baseline was 8.8 mL/min, and eGFR/1.73 m^2 improve in baseline was 8.6 mL/min (P < 0.001).

Meanwhile, affected-side eGFR and eGFR/1.73 m^2 improve by 22.1% after surgery in the overall cohort. As shown in Supplementary Fig. 1A-B, paired trend plots directly show an overall postoperative increase in eGFR and eGFR/1.73 m^2 across the full cohort. Although individual recovery outcomes are heterogeneous, most connecting lines slope upward. In addition, as shown in Fig. 3A-B, urinary tract CT scans demonstrate marked postoperative relief of hydronephrosis in patients undergoing duplex kidney heminephrectomy.

3.2 Baseline characteristics and symptom outcomes in the resection and reconstruction groups

Table 2 summarizes the baseline characteristics of the two groups. In the resection group, 17 patients had a complete DCS, 17 presented with severe preoperative hydronephrosis, and 20 had preoperative clinical symptoms. In the reconstruction group, 13 patients had a complete DCS, 17 presented with severe preoperative hydronephrosis, and 21 had preoperative clinical symptoms. Postoperatively, 2 patients in the resection group still had clinical symptoms, whereas all patients in the reconstruction group recovered well. In terms of renal functional recovery, total eGFR and eGFR/1.73 m^2improved by 0.2% in the resection group and by 11.6% in the reconstruction group.

Table 2
Baseline characteristics and postoperative symptom and global renal function outcomes in the resection and reconstruction groups

Variable	Resection group (n = 23)	Reconstruction group (n = 28)
Age, yr, median (IQR)	35 (25–44)	37 (25–46)
BMI, kg/m², median (IQR)	23.2 (20.1–26.3)	23.4 (20.2–25.2)
Male sex, n (%)	5 (21.7)	10 (35.7)
Hypertension, n (%)	3 (13.0)	4 (14.3)
Diabetes, n (%)	0	2 (7.1)
Left-sided duplex kidney, n (%)	17 (73.9)	12 (42.9)
Upper-moiety involvement, n (%)	20 (90.0)	15 (53.6)
Complete duplex kidney, n (%)	17 (73.9)	13 (46.4)
Severe hydronephrosis, n (%)	17 (73.9)	17 (60.7)
Body surface area, m², mean (SD)	1.7 (0.20)	1.7 (0.2)
Preoperative clinical symptoms, n (%)	20 (87.0)	21 (75.0)
Preoperative serum creatinine, μmol/L, mean (SD)	65.0 (13.7)	71.7 (18.1)
Preoperative total eGFR, mL/min, mean (SD)	106.5 (17.9)	100.2 (23.9)
Preoperative total eGFR, mL/min per 1.73 m², mean (SD)	103.9 (17.5)	99.8 (24.3)
Postoperative clinical symptoms, n (%)	2 (8.7)	0
Postoperative serum creatinine, μmol/L, mean (SD)	64.9 (13.3)	66.2 (17.2)
Postoperative total eGFR, mL/min, mean (SD)	108.1 (18.2)	111.7 (30.1)
Postoperative total eGFR, mL/min per 1.73 m², mean (SD)	105.1 (15.8)	110.9 (29.2)

BMI, body mass index; eGFR, estimated glomerular filtration rate; IQR, interquartile range; SD, standard deviation.

3.3 Analysis of perioperative outcomes

Table 3 summarizes the perioperative outcomes of the two groups. In the resection group, the median operative time was 158 (135–195) minutes, estimated blood loss was 100 (50–200) mL, renal artery clamp was 6 cases, blood transfusion was 2cases, median hospital stay was 5 (4–7) days, drain indwelling time was 4 (3–5) days, and catheter indwelling time was 1 (1–2) day. One patient required

postoperative blood transfusion. The overall complications rate was 52.2%. One patient (8.7%) experienced subcapsular hematoma and underwent percutaneous perinephric drainage. Two patients (8.7%) experienced Clavien-Dindo grade ≥b. One patient developed urinary leakage (Clavien-Dindo grade ≥b) and underwent heminephrectomy, and another patient developed ureteral stump inflammation (Clavien-Dindo grade ≥b) and underwent ureteral stump excision. The overall success rate in this group was 91.3%. In the reconstruction group, the median operative time was 124 (101–145) minutes, estimated blood loss was 20 (20–20) mL, median hospital stay was 4 (4–4) days, drain indwelling time was 3 (3–3) days, and catheter indwelling time was 7 (7–7) days. Notably, no patient in this group required intraoperative blood transfusion. The overall complications rate was 7.1%. Only one patients (9.5%) developed infectious fever>38.0℃ (Clavien-Dindo grade ≥a). The surgical success rate was 100%.

Table 3
Perioperative outcomes in the resection and reconstruction groups

Variable	Resection group (n = 23)	Reconstruction group (n = 28)
Operative time, min, median (IQR)	158 (135–195)	124 (101–145)
Estimated intraoperative blood loss, mL, median (IQR)	100 (50–200)	20 (20–20)
Renal artery clamping, n (%)	4 (17.4)	0
Blood transfusion, n (%)	2 (8.7)	0
Postoperative hospital stay, d, median (IQR)	5 (4–7)	4 (4–4)
Drainage tube duration, d, median (IQR)	4 (3–5)	3 (3–3)
Urinary catheter duration, d, median (IQR)	1 (1–2)	7 (7–7)
Overall complications, n (%)	12 (52.2)	2 (7.1)
Minor, Clavien–Dindo grade I–II	9 (39.1)	2 (7.1)
Major, Clavien–Dindo grade III–IV	3 (13.1)	0
Complications in details, n (%)[a]		
Transient fever>38.0℃ / physical cooling (grade I)	1 (4.3)	1 (3.6)
Infectious Fever>38.0℃ / additional antibiotics (grade II)	6 (26.1)	1 (3.6)
Subcapsular hematoma / percutaneous perinephric drainage (grade IIIa)	1 (4.3)	0
Urine leak / heminephrectomy (grade IIIb)	1 (4.3)	0
Anaemia / clinical observation (grade I)	2 (8.7)	0
Anaemia / Blood transfusion (grade II)	2 (8.7)	0
Stump inflammation / ureteral stump excision (grade IIIb)	1 (4.3)	0

IQR, interquartile range. A dash indicates that a test statistic was not applicable or not reported.

[a] Some cases developed concurrent complications.

3.4 Differential recovery of affected-side renal function

Supplementary table 1 summarizes the renal functional recovery of the two groups. In the resection group, affected-side eGFR improved by 6.4 mL/min from baseline, and eGFR/1.73 m^2 improved by 6.3 mL/min from baseline. However, the reconstruction group showed a more favorable recovery trend, with

affected-side eGFR improving by 8.7 mL/min from baseline and eGFR/1.73 m^2 improving by 8.4 mL/min from baseline.

Table 1 shows that postoperative affected-side eGFR and eGFR/1.73 m^2 are significantly higher than preoperative values in both the resection and reconstruction groups. Affected-side renal function improves by 16.7% after surgery in the resection group and by 26.3% after surgery in the reconstruction group, and the within-group preoperative-to-postoperative differences are statistically significant ($P < 0.001$). Within-group paired analysis shows that postoperative affected-side eGFR is significantly higher than the preoperative value in both the resection and reconstruction groups (Supplementary Fig. 1C-F). In addition, urinary tract CT scans demonstrate marked postoperative relief of hydronephrosis in patients undergoing end-to-side ureteroureterostomy (Fig. 3C-D) and ureteroneocystostomy (Fig. 3E-F).

4.Discussion

DCS is a rare congenital anomaly of the urinary tract and is usually asymptomatic. However, when complicated by ureteral stricture, Some adult patients present with recurrent urinary tract infection, urinary frequency, chronic flank pain, and refractory urinary incontinence[12–14]. For patients with duplex kidney and ureteral duplication who have poor drainage and severe hydronephrosis, particularly when renal function is poor, clinicians often recommend heminephrectomy[15–17]. However, because the anatomic boundary between the upper and lower moieties is often indistinct and the vascular distribution is complex, the traditional resection-based paradigm is associated with substantial trauma, technical difficulty, vascular injury, and loss of residual renal function[4, 18].

Previous studies generally consider an upper duplex moiety with severe dilation and hydronephrosis, recurrent infection, or severely impaired function to represent irreversible dysplasia. Preserving this tissue is unlikely to improve renal function and may increase the risks of secondary infection, refractory hypertension, or even malignant transformation[19]. Therefore, heminephrectomy has long been regarded as a standard treatment, especially for patients with upper moiety split renal function below 10% to 15% or infection that is difficult to control[20, 21]. However, in patients with residual function and anatomy suitable for reconstruction, nephron-sparing strategies such as ureteroureterostomy or ureteroneocystostomy are receiving increasing attention[12]. Considerable experience with these reconstructive procedures has been accumulated in children. Studies by Chacko et al.[4] and Yang et al.[22] confirm that they effectively relieve obstruction, avoid loss of renal parenchyma, and promote recovery of split renal function. In contrast, reports on heminephrectomy and upper urinary tract reconstruction in adult duplex kidney are scarce, with most available data coming from small retrospective studies[18, 23]. Through descriptive comparison of data from earlier small observational studies, Michaud et al.[23] report that heminephrectomy and ureteroureterostomy are safe and effective for patients with duplex kidney. The two approaches have similar postoperative complication and overall success rate, whereas heminephrectomy carries a higher risk of residual renal function loss. Evans et al.[18] systematically compare upper-pole partial nephrectomy with ipsilateral ureteroureterostomy for complete duplex kidney and ureteral duplication. They suggest that, even in patients with a

nonfunctioning upper moiety, ureteroureterostomy should be prioritized when the residual renal unit has relatively normal structure and no complex bladder disease. The advantage of this procedure lies in higher renal function preservation and a lower risk of residual renal function loss, which is in line with our results. Our study shows that both heminephrectomy and upper urinary tract reconstruction can relieve symptoms and improve affected-side renal function in these patients.

With the widespread adoption of minimally invasive principles and technologies, robot-assisted laparoscopic surgery has demonstrated distinct advantages in upper urinary tract reconstruction[9, 24, 25]. First, the articulated instruments and high-definition three-dimensional visualization provided by the robotic platform facilitate accurate identification and preservation of the normal ureter[26]. This advantage is especially valuable in duplex systems, where the duplicated ureter and the normal ureter share a common adventitial sheath and are prone to misidentification. Second, during ureteroureterostomy or ureteroneocystostomy, robotic suturing provides enhanced ergonomics and tremor reduction, allowing for a watertight, tension-free anastomosis with precise mucosal alignment[27]. This technical benefit may explain the absence of anastomotic stricture or urinary leakage observed in the reconstruction group of the present study. Third, when heminephrectomy is performed, the enhanced precision of robotic dissection allows for more accurate demarcation of the parenchymal resection plane, thereby reducing the risk of unintended injury to the residual healthy parenchyma. These technical advantages collectively contributed to the favorable perioperative outcomes observed in our cohort, including shorter operative time, decreased blood loss, and fewer complications. In the present study, robot-assisted surgery effectively alleviated clinical symptoms, promoted recovery of affected-side split renal function, and preserved total renal function in patients with duplex collecting system and ureteral strictures.

In the present study, the reconstruction group showed greater postoperative increases in eGFR and eGFR/1.73 m^2 than the resection group. These results suggest that, when surgical indications are strictly selected, upper urinary tract reconstruction can combine the benefits of minimally invasive treatment with renal function preservation. The apparent paradox that heminephrectomy can lead to both loss of functional nephrons from the affected moiety and a net postoperative increase in ipsilateral split renal function warrants further mechanistic clarification. In duplex kidneys, the upper and lower moieties share a complex and often intertwined vascular network, with frequent cross-circulation between the two parenchymal units. When heminephrectomy is performed, the parenchymal transection plane is typically identified by visual inspection, palpation, or intraoperative ultrasound; however, a distinct avascular demarcation line is often absent. Consequently, monopolar or bipolar electrocautery applied along the resection margin inevitably induces thermal injury and microvascular thrombosis in the adjacent preserved parenchyma, leading to the loss of some viable nephrons that were originally functional[4, 20]. In addition, temporary renal artery clamping-sometimes required for hemorrhage control during parenchymal resection-may exacerbate ischemic injury to the remnant moiety. Despite this unavoidable loss of a subset of nephrons, the overall ipsilateral split renal function may still show a net increase postoperatively. This is attributable to the compensatory hyperfiltration and functional hypertrophy of the remaining viable nephrons within the preserved parenchyma, which occurs once the obstructed or

dysplastic moiety is removed and the ipsilateral urinary drainage is restored.By contrast, the core mechanism underlying the higher safety and lower complication rate of robot-assisted upper urinary tract reconstruction is that the procedure does not require identification and separation of a transection plane within the renal parenchyma, thereby avoiding major bleeding and stump-related complications associated with renal resection[17, 21]. At the same time, robotic visualization and suturing improve anastomotic quality in urinary reconstruction and reduce the incidence of anastomosis-related complications[5, 6]. This strategy maximizes the preserved nephron mass and provides a structural basis for compensatory recovery of functional nephrons after relief of obstruction. In other words, the magnitude of functional recovery depends on the balance between two competing forces: the extent of unavoidable nephron loss at the resection margin versus the degree of compensatory hyperfiltration in the remnant parenchyma. This dual effect may explain why, in our cohort, the reconstruction group-which completely avoided parenchymal resection-showed greater improvement in affected-side split renal function than the resection group.

This study has several limitations. First, it is a single-center retrospective cohort study, and procedure selection is nonrandomized and based on preoperative imaging assessment and surgeon judgment. Second, the small sample size precludes multivariate adjustment for confounders. Third, follow-up is short and is not sufficient to evaluate long-term maintenance of renal function, anastomotic stricture, reflux, recurrent infection, or risk of reintervention. Fourth, this study is completed by an experienced robotic surgical team, and the generalizability of the findings to centers with different surgical volumes or technical platforms requires further validation.

5.Conclusions

Our single-center study demonstrated that both robot-assisted heminephrectomy and robot-assisted upper urinary tract reconstruction can be safely and effectively applied in adult patients with duplex collecting system and ureteral strictures. Between the two, upper urinary tract reconstruction was associated with greater improvement in affected-side renal function, a lower complication rate, and a higher success rate. However, future prospective, randomized studies with larger cohorts are warranted to validate the long-term outcomes of both procedures and to further optimize patient selection criteria.

Abbreviations

eGFR: estimated glomerular filtration rate

MDRD: Modification of Diet in Renal Disease

BMI, body mass index

IQR: interquartile range

SD: standard deviation

DCS: duplex collecting system

Declarations

Compliance with ethics guidelines

There are no conflicts of interest or competing financial interests. The study protocol and written informed consent were approved by the ethics committee of the Third Medical Center, Chinese PLA General Hospital, with approval No. S-2024-208-02. All participants provided written informed consent in accordance with the Declaration of Helsinki.

Open access

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

Author Contribution

Xu Zhang, Run Zhu, and Yang Fan: study concept and design; Hanfeng Wang, Fei Yu, and Yundong Xuan: acquisition of data; Kailong Wang, Xiaohang Li, and Long Yi: analysis and interpretation of data; Zhi Li, Chao Gao, Shujun Yang: drafting of the manuscript; Zhi Li and Fang Wang: statistical analysis; Xu Zhang, Run Zhu , Yang Fan: supervision.

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Figures

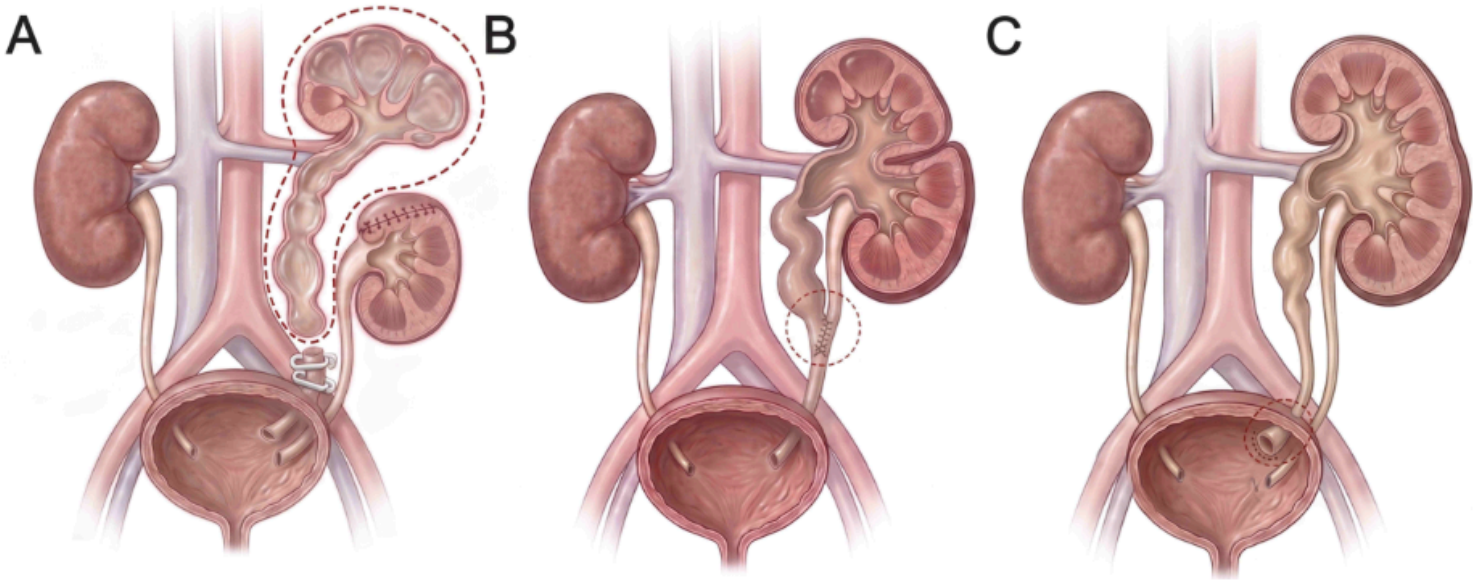


Figure 1

Schematic diagrams of different robot-assisted procedures for duplex kidney. (A) Robot-assisted heminephrectomy for duplex kidney; (B) robot-assisted end-to-side ureteroureterostomy for a duplicated ureter; (C) robot-assisted ureteroneocystostomy for a duplicated ureter.

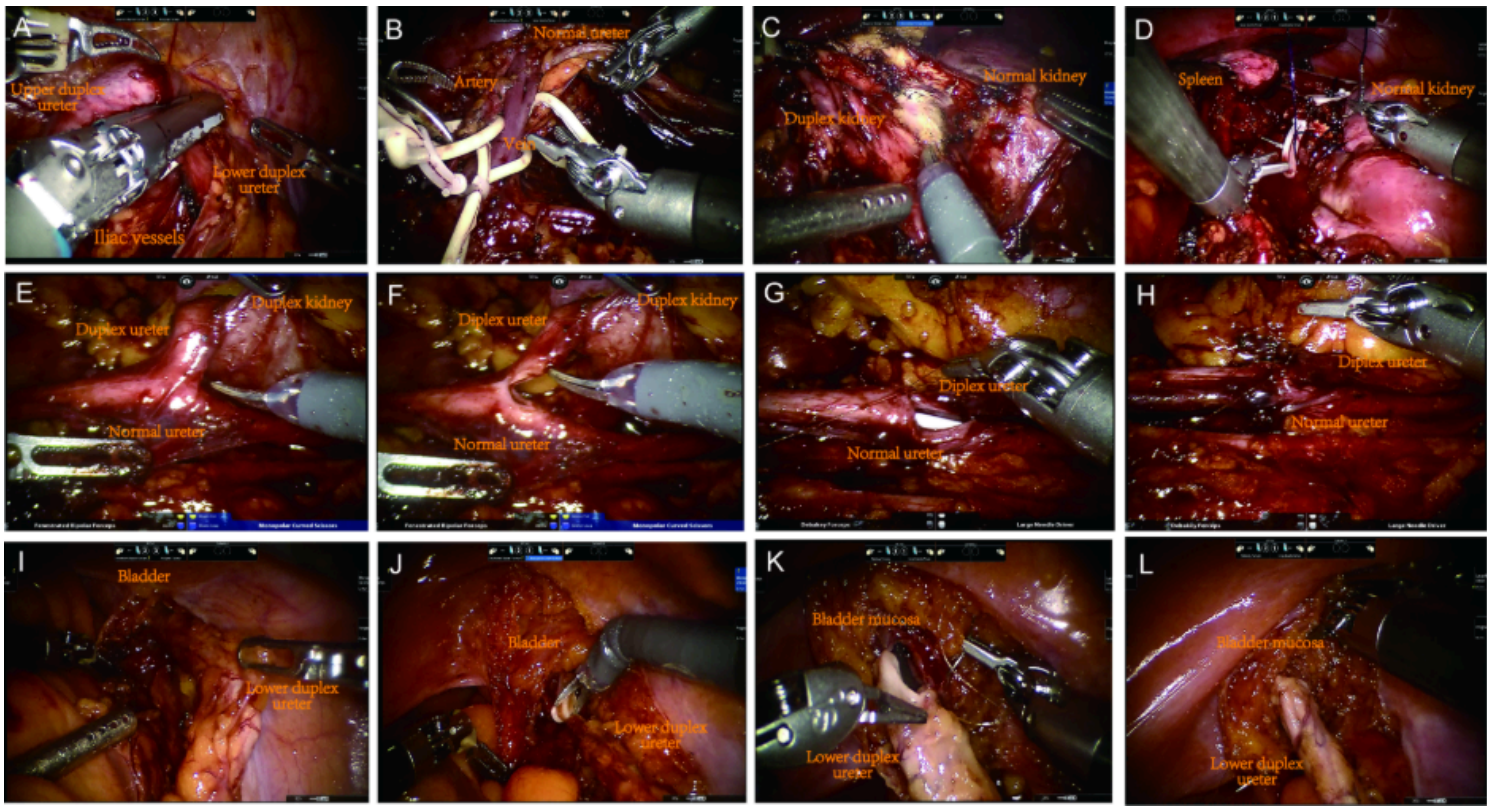


Figure 2

Surgical steps and annotations for different robot-assisted procedures for duplex kidney. (A–D) Surgical steps for robot-assisted heminephrectomy in Patient 1: (A) transection of the duplicated ureter anterior to the iliac vessels; (B) dissection and preservation of the hilar supplying vessels; (C) dissection along the boundary between the duplex moiety and normal renal parenchyma; (D) closure of the residual renal parenchymal defect. (E–H) Surgical steps for robot-assisted end-to-side ureteroureterostomy in Patient 2: (E) dissection of the confluence between the duplicated ureter and the normal ureter; (F) transection at the confluence between the duplicated ureter and the normal ureter; (G) end-to-side anastomosis between the duplicated ureter and a lateral wall incision of the normal ureter; (H) completed end-to-side ureteroureterostomy. (I–L) Surgical steps for robot-assisted ureteroneocystostomy in Patient 3: (I) dissection of the junction between the distal duplicated ureter and the bladder; (J) transection at the ureterovesical junction of the duplicated ureter; (K) anastomosis between the distal end of the duplicated ureter and the bladder mucosal incision; (L) closure of the bladder muscular layer after submucosal embedding of the ureter.

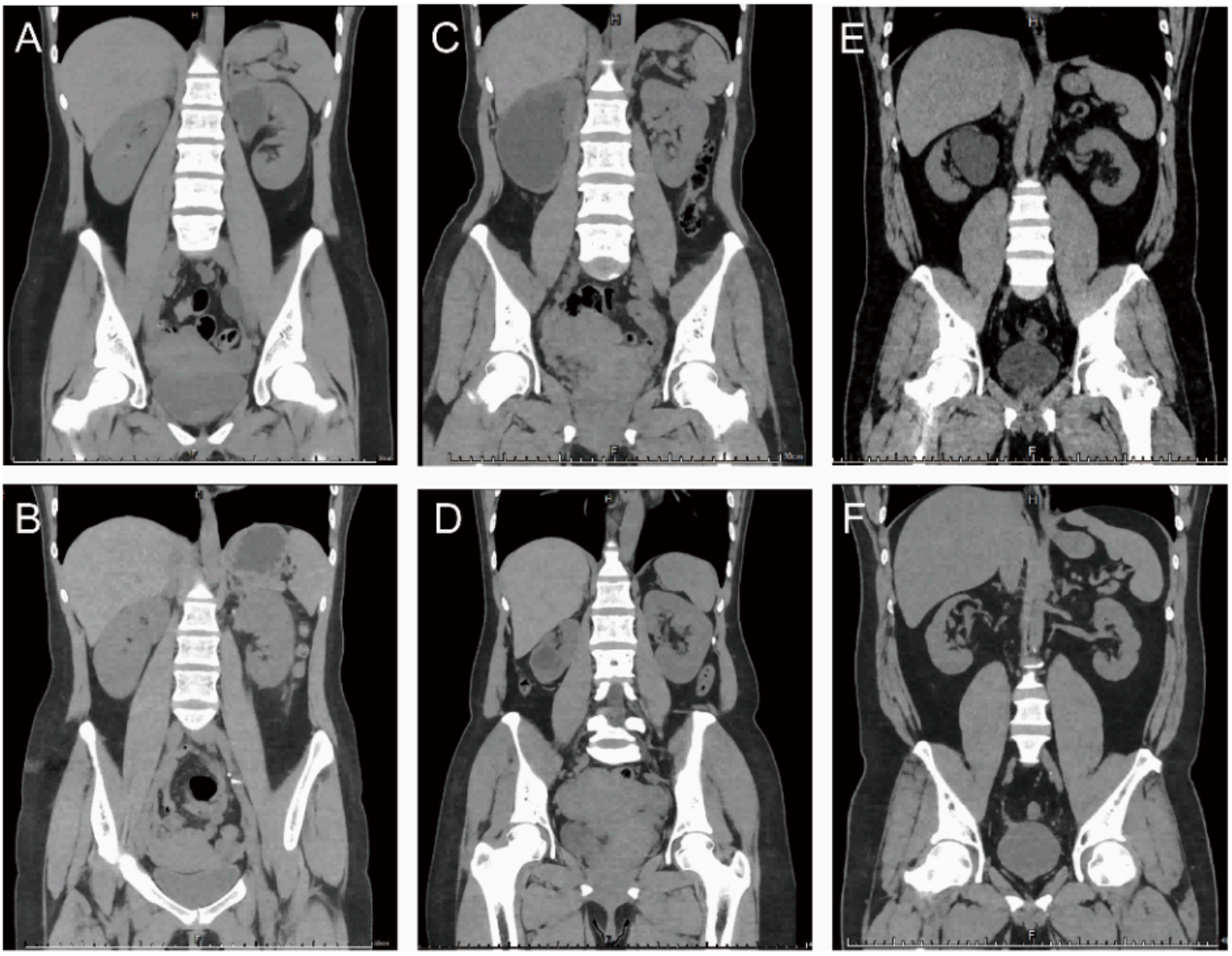


Figure 3

Imaging characteristics before and after treatment of duplex kidney according to surgical procedure. (A) Preoperative noncontrast CT image of Patient 1 before heminephrectomy for duplex kidney, showing hydronephrosis of the upper moiety; (B) postoperative noncontrast CT image of Patient 1 after heminephrectomy, showing relief of hydronephrosis in the upper moiety; (C) preoperative noncontrast CT image of Patient 2 before end-to-side ureteroureterostomy, showing hydronephrosis of the lower moiety; (D) postoperative noncontrast CT image of Patient 2 after end-to-side ureteroureterostomy, showing relief of hydronephrosis in the lower moiety; (E) preoperative noncontrast CT image of Patient 3 before ureteroneocystostomy, showing hydronephrosis of the upper moiety; (F) postoperative noncontrast CT image of Patient 3 after ureteroneocystostomy, showing relief of hydronephrosis in the upper moiety. CT = computed tomography.

Supplementary Files

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- SupplementaryFig.docx
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- Supplementarytable1.docx