



Renal function after ureteral reconstruction surgery in patients with solitary kidney

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Background: Ureteral strictures (US) could lead to impaired kidney function, which was alleviated by ureteral reconstruction surgery. However, solitary kidney (SK) patients with US were more complicated to treat. This study aimed to evaluate the impact of reconstruction surgery on renal function based on estimated glomerular filtration rate (eGFR) in patients with SK.

Methods: We retrospectively enrolled patients who underwent reconstruction surgery between April 2014 to March 2022. eGFR was measured pre- and postoperatively. The ‘static renal function’ was defined as a change in eGFR of 20% or less at the last follow-up, and the ‘worsening renal function group’ was defined as a decrease of greater than 20%.

Results: A total of 61 SK patients were involved. The success rate of ureteral reconstruction surgery was 90.16% (55/61). The median follow-up time was 20.8 months (range, 3.7–109.2 months). The median eGFR was 65.5 (range, 15.1–99.9) and 65.3 (range, 3.8–123.4) mL/min/1.73 m² at the baseline and the last follow-up. No statistically significant difference in eGFR was observed between the preoperative baseline and last follow-up visits (P=0.58). However, in patients with baseline renal dysfunction [chronic kidney disease (CKD) stage 3–5], the eGFR significantly improved at the last follow-up compared to the baseline (P=0.02). Three patients developed a ‘worsening renal function’ (4.92%). Besides, the systolic blood pressures (SBP) at follow-up significantly reduced compared to the preoperative baseline (P=0.002).

Conclusions: Ureteral reconstruction surgery is an effective treatment to preserve renal function, which also achieves a high success rate and is associated with the reduction of SBP for SK patients with US.

Keywords: Solitary kidney (SK); ureteral reconstruction surgery; renal function; blood pressure (BP)

Submitted Feb 10, 2024. Accepted for publication Apr 25, 2024. Published online Jun 21, 2024.

doi: 10.21037/tau-24-82

View this article at: <https://dx.doi.org/10.21037/tau-24-82>

Introduction

Background

Ureteral strictures (US) are associated with severe hydronephrosis, leading to the impairment of kidney function, which commonly manifests as flank pain and urinary retention (1-3). To alleviate obstruction and preserve renal function, ureteral reconstruction surgeries may be used to treat US.

Rationale and knowledge gap

However, solitary kidney (SK) patients with US may be much more complicated to treat, and the impact of ureteral reconstruction surgery on renal function recoverability cannot be guaranteed (4,5).

Several studies have demonstrated the impact of pyeloplasty on renal function recoverability. It has been reported that the effects of pyeloplasty on renal function recoverability depends on the patient's age, preoperative split renal function, renal perfusion, and degree of hydronephrosis (6,7). Regarding SK patients, several studies have focused on the renal function outcomes after pyeloplasty. In another retrospective cohort study, the authors extended the sample size to 62 SK patients receiving pyeloplasty and found that pyeloplasty in SK preserved renal function in 90.4% of the patients (8). However, renal function recoverability after other ureteral reconstruction surgeries in SK patients has not been discussed thoroughly in the literature.

Furthermore, the impact of ureteral reconstruction surgery on blood pressure in SK patients has not been studied before. Masked hypertension may occur in SK children and systolic blood pressure (BP) loads are higher in children with congenital SK (CSK) (9). Besides, previous study indicated that hydronephrosis was associated with elevated blood pressure, which could be reduced by surgical management of the obstruction in adults and children (10). These discoveries inspired us to explore the impact of ureteral reconstruction surgery on blood pressure in SK patients.

Objective

Therefore, we propose the following hypotheses that the renal function could be preserved rather than improved after ureteral reconstruction surgeries in SK. In the present study, we aimed to investigate the renal function recoverability and blood pressure outcomes after ureteral reconstruction surgeries. We present this article in accordance with the STROBE reporting checklist (available at <https://tau.amegroups.com/article/view/10.21037/tau-24-82/rc>).

Methods

Patient and study design

For the sample cases, we collected a retrospective cohort of patients diagnosed with hydronephrosis and treated with ureteral reconstruction surgery from April 2014 to March 2022 from Peking University First Hospital, Beijing Tsinghua Changgung Hospital, Beijing Friendship Hospital, Beijing Jianguo Hospital, Emergency General Hospital. Renal function was assessed by estimated glomerular filtration rate (eGFR). Criteria for selecting the subjects were as follows: (I) patients were diagnosed with US and SK confirmed by imaging; (II) patients underwent ureteral reconstruction surgery, including lingual mucosal onlay graft ureteroplasties (LMG), ureter anastomosis (UA), ureteral re-implantations (UR), boari flap-Psoas hitch surgeries (BPS), ileal ureter replacements (IUR) and modified laparoscopic pyeloplasty (MLP). Exclusion criteria: (I) the follow-up data were incomplete; (II) with new-onset chronic kidney disease after operation. The study was approved by the Ethics Committee of Peking University First Hospital (No. 2019-134), Beijing Tsinghua Changgung Hospital, Beijing Friendship Hospital, Beijing Jianguo Hospital, and Emergency

Highlight box

Key findings

- Ureteral reconstruction surgery is an effective treatment to preserve renal function and control blood pressure, which also achieves a high success rate in patients with solitary kidney.

What is known and what is new?

- Pyeloplasty could preserve renal function in most patients with solitary kidney.
- Several ureteral reconstruction surgeries could preserve renal function and reduce systolic pressure.
- Baseline renal dysfunction was associated with postoperative improvement of estimated glomerular filtration rate.

What is the implication, and what should change now?

- Ureteral reconstruction surgery might be a feasible and safe approach to preserve renal function in patients with solitary kidney.

General Hospital were also informed and approved the study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was obtained from all subjects or their legal guardians.

All surgeries achieved 8-french catheter passing through the US during operation in different surgical procedures. Surgical success was defined as the disappearance of clinical symptoms and radiological relief of obstruction. Subjects were prescribed reconstructive surgery based on consultation with their treating surgeon.

Based on the clinical practice guidelines for chronic kidney disease, the interindividual coefficient of variation of body surface-adjusted glomerular filtration rate (GFR) within the normal population is approximately 15% to 20% (11). For the sake of research needs, we defined the 'worsening renal function' group as a decrease greater than 20% in eGFR since the last follow-up compared to baseline eGFR and defined the 'static renal function' group as a decrease less than 20% in eGFR. Based on a previous study, the reduction in systolic and diastolic BP was approximately 20 and 15 mmHg when impaired renal function was 20% (12). Similarly, we defined 'blood pressure reduction' as a decrease in systolic pressure by more than 20 mmHg and diastolic pressure by more than 15 mmHg at follow-up compared to preoperative baseline, and patients below the standard were defined as a 'blood pressure static' group.

Technique

Robot-assisted laparoscope was performed using da Vinci Si surgical systems (N=16, Intuitive Surgical, Sunnyvale, CA, USA) and KangDuo-Surgical Robot-01 system (N=1, Suzhou KangDuo Robot Co., Ltd, Suzhou, China) (13,14). We used the 3D image for intraoperative navigation by the surgeon's cognitive fusion. Anti-refluxing procedures were performed according to surgeon preference. It should be noted that in SK patients, the crossing vessels were prudently protected to ensure enough blood supply.

Preoperative preparation and postoperative treatment

According to different locations and lengths of the stricture, all patients had a standard perioperative treatment plan for various surgical techniques, summarized as our surgical strategies for ureteral reconstruction in our previous study (13).

Before surgery, we mainly focused on renal function

and took measures to protect renal function in severe hydronephrosis, such as nephrostomy. After the surgery, a liquid diet was initiated until patients could adapt to a regular diet. The double-J (D-J) tube was routinely removed 2 months after the operation. For patients with preoperative percutaneous nephrostomy (PCN), PCN was removed when there was no abnormality in antegrade pyelography 1 week after removing the D-J tube.

During follow-up, hydronephrosis and symptoms were closely monitored with an ultrasound examination and computed tomography urography (CTU) every 3 to 6 months postoperatively. The patients with symptoms and imaging evidence of hydronephrosis would perform a retrograde pyelogram.

Data collection

The following demographic and clinical characteristics were collected from the RECUTTER (Reconstruction of Urinary Tract: Technology, Epidemiology, and Result) database, including age, gender, disease characteristics, perioperative serum creatinine (a week before and after surgery), urea nitrogen, and medical histories. The history of hypertension was mainly determined by patients' self-reports and medical records. We updated patient information according to medical records subsequently. We used the four-variable MDRD equation to calculate eGFR. The perioperative average blood pressure was collected from the hospital medical record system. Follow-up data were obtained from the patient's last outpatient review and contact, including laboratory examinations, blood pressure, and accessible records of urological symptoms. The overall follow-up time was from surgery to the last contact. All blood pressures were averaged by two measurements using an electronic or mercurial floor stand model sphygmomanometer.

Statistical analysis

After screening by inclusion and exclusion criteria, the final sample size was determined based on data from the RECUTTER database. We performed subgroup analysis to control bias. All quantitative variables were treated as continuous variables.

To process the data, we utilized the Chi-square test to analyze the correlation of categorical data. The differences of continuous variables among groups were compared by the non-parametric test, including the Mann-Whitney

Table 1 Patients' characteristics

Variables	Ureteral reconstruction surgery (N=61)
Age (years)	42.0 (15.0–75.0)
Sex (male)	26 (42.6)
Side (right)	36 (59.0)
Type of SK (CSK)	27 (44.3)
BMI (kg/m ²)	22.5 (13.8–31.2)
Estimated blood loss (mL)	50.0 (5.0–800.0)
Postoperative hospital stays (days)	7.0 (3.0–46.0)
Preoperative D-J tube indwelling (yes)	30 (49.2)
Preoperative nephrostomy (yes)	34 (55.7)
History of reconstruction surgery	15 (24.6)
Etiology of ureteral stricture	
Congenital ureterostenosis	39 (63.9)
Infectious inflammation	0 (0.0)
Trauma	2 (3.3)
Iatrogenic injury	9 (14.8)
Ureteral calculus	9 (14.8)
Others	2 (3.3)
Surgical method	
Open surgery	10 (16.4)
Laparoscope	34 (55.7)
Robot-assisted laparoscope	17 (27.9)
Baseline CKD stage	
1	5 (8.2)
2	30 (49.2)
3	17 (27.9)
4	9 (14.8)
Surgical procedure	
Lingual mucosal onlay graft ureteroplasties	2 (3.3)
Ureter anastomosis	3 (4.9)
Ureteral re-implantations	8 (13.1)
Boari flap-psoas hitch surgeries	6 (9.8)
Ileal ureter replacements	13 (21.3)
Modified laparoscopic pyeloplasty	29 (47.5)

Table 1 (continued)

Table 1 (continued)

Variables	Ureteral reconstruction surgery (N=61)
Location of stricture	
Upper ureter	45 (73.8)
Lower ureter	16 (26.2)
Length of stricture (cm)	1.5 (1.0–15.0)

Data are presented as median (range) or number (percentage). Chi-square test and Kruskal-Wallis test were conducted to compare the difference of data between groups. SK, solitary kidney; BMI, body mass index; D-J, double-J; CSK, congenital solitary kidney; Lower ureter, from the inferior margins of the sacrum to the bladder; 'Others' in etiology, included endometriosis and retroperitoneal fibrosis; CKD, chronic kidney disease.

U test and the Wilcoxon matched pair rank test. The correlation between continuous variables was analyzed by Spearman's rank correlation. Statistical analysis was performed using SPSS version 25.0 for Windows (IBM Corporation, Armonk, New York, USA). A P value of <0.05 demonstrated a significant statistical difference for all tests.

Results

We included 63 patients at first, and two patients were excluded for relatively incomplete follow-up data, none of patients were excluded for new onset chronic kidney disease. Therefore, the final number included in the study was 61 patients. The severe symptoms that disrupted work or sleep (N=24), repeated urinary tract infection (N=5), severe degree of hydronephrosis (N=6), and impaired renal function (N=26) were considered indications for surgery

The median age of the cohort was 42 years (range, 15–75 years), and the median follow-up time was 20.8 months (range, 3.8–109.2 months). Patients' characteristics are shown in *Table 1*. The cohort contained six categories of ureteral reconstruction surgeries, including LMG (N=2), UA (N=3), UR (N=8), BPS (N=6), IUR (N=13) and MLP (N=29). In the cohort, there were 17 patients receiving robot-assisted laparoscope surgery which involved LMG, MLP, BPS, and IUR.

Fifteen (24.59%, 15/61) patients had a history of ureteral reconstruction surgeries or balloon dilatation, including five patients with balloon dilatation, four with pyeloplasty, two with UA, two with BPS, one with UR, and one with the

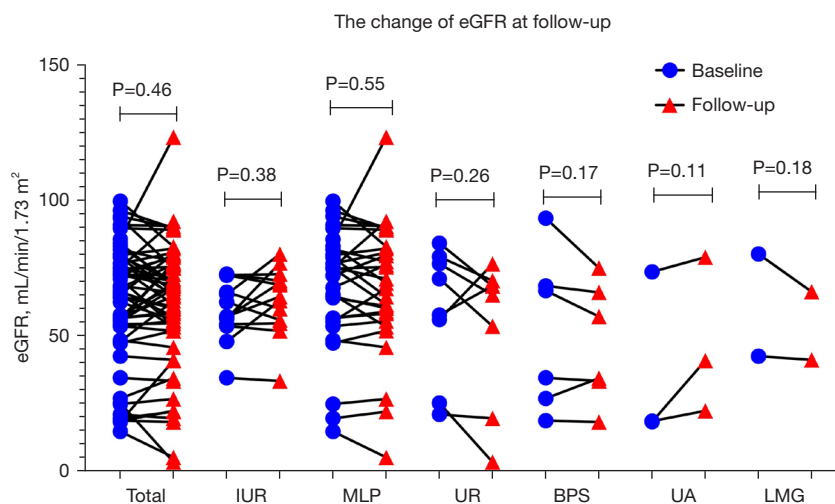


Figure 1 The change of eGFR after ureteral reconstruction. The eGFR between pre-operative and the last follow-up was compared with a nonparametric matched pair test in different surgical techniques. LMG, lingual mucosal only graft ureteroplasties; UA, ureter anastomosis; UR, ureteral re-implantations; BPS, Boari flap-psoas hitch surgeries; IUR, ileal ureter replacements; MLP, modified laparoscopic pyeloplasty; eGFR, estimated glomerular filtration rate.

dissolution of ureteral scar contracture.

There were 34 patients diagnosed with acquired SK (ASK) and 27 patients with CSK. The etiology of US was diverse, comprising 39 cases of congenital malformation, 2 cases of trauma, 9 cases of iatrogenic procedures, 9 cases of urinary calculi, 1 case of endometriosis and 1 case of retroperitoneal fibrosis (Table 1).

The ureteral reconstruction surgery achieved a 90.16% (55/61) success rate, with no serious intraoperative complications. For different anastomosis procedures, the success rate reached 92.86% (13/14) in ureter-bladder (BPS and UR), 93.75% (30/32) in ureter-ureter (UA and MLP), 92.31% (12/13) in ureter-ileum, and 100% (2/2) in lingual mucosal only flap ureteroplasty.

For four cases with postoperative complications, the detailed records are as follows: D-J stent migration (Clavien-Dindo grade IIIb) occurred on one patient and we adjusted the stent position by emergency operation; one patient had an increased count of white blood cells with fever, resulting from operation stress (Clavien-Dindo grade I); one patient had small bowel obstruction (Clavien-Dindo grade IIIa); one patient developed abdominal incision fat liquefaction (Clavien-Dindo grade II). At follow-up, four patients (6.56%, 4/61) remained or progressed to radiologically severe hydronephrosis, two of whom developed uremia requiring hemodialysis. The clinical symptoms of 5 patients (8.20%, 5/61) aggravated, involving

four patients with continued flank pain and one patient with a new urinary infection at follow-up.

Renal function outcomes

The comparison between patients' eGFR (mL/min/1.73 m²) at the last follow-up and preoperative baseline showed no significant differences in the whole cohort (65.3 vs. 65.5, P=0.46), which was consistent in IUR (64.66 vs. 57.39, P=0.38), MLP (69.65 vs. 75.03, P=0.55), UR (64.59 vs. 66.91, P=0.26), BPS (46.04 vs. 50.84, P=0.17), UA (41.17 vs. 18.89, P=0.11), or LMG (53.96 vs. 61.56, P=0.18) (Figure 1, Table 2).

There were no significant differences in the baseline eGFR compared with the follow-up eGFR in open surgery (55.86 vs. 68.17, P=0.29, N=10), laparoscope surgery (68.34 vs. 64.97, P=0.75, N=34) and robotic-assisted laparoscope surgery (64.76 vs. 64.66, P=0.91, N=17). For patients with stricture of lower (66.33 vs. 64.67, P=0.35, N=16) and upper ureter (61.46 vs. 68.69, P=0.23, N=45), we also observed no significant differences between baseline and follow-up eGFR.

A total of three (4.92%, 3/61) patients met the criteria for 'worsening renal function' while 58 patients maintained 'static renal function' based on the last follow-up outcomes. Among these cases, two had baseline chronic kidney disease (CKD) stage 4 (15 < eGFR < 30 mL/min/1.73 m²), and one

Table 2 The clinical outcomes of patients

Variables	Ureteral reconstruction surgery (N=61)
Follow-up time (months)	20.8 (3.7–109.2)
Preoperative serum creatine ($\mu\text{mol/L}$)	96.2 (59.0–383.7)
Preoperative eGFR ($\text{mL}/\text{min}/1.73 \text{ m}^2$)	65.5 (15.1–99.9)
Follow-up eGFR ($\text{mL}/\text{min}/1.73 \text{ m}^2$)	65.3 (3.8–123.4)
Preoperative systolic pressure (mmHg)	125.0 (96.0–180.0)
Follow-up systolic pressure (mmHg)	123.0 (90.0–190.0)
Preoperative diastolic pressure (mmHg)	80.0 (60.0–110.0)
Follow-up diastolic pressure (mmHg)	80.0 (60.0–110.0)
Worsening renal function (yes)	3 (4.9)

Data are presented as median (range) or number (percentage). eGFR, estimated glomerular filtration rate.

had baseline CKD stage 2 ($60 < \text{eGFR} < 90 \text{ mL}/\text{min}/1.73 \text{ m}^2$). Case 1, with duplicated right kidney and ureters, underwent UR of two right ureters. Mild hydronephrosis was observed with no accompanying symptoms during follow-up. In Case 2, despite undergoing ureteral reimplantation, the hydronephrosis worsened, and renal function declined during follow-up. Case 3 underwent MLP with thin parenchymal thickness before surgery (baseline serum creatinine $348 \mu\text{mol/L}$), and serum creatinine progressively increased during follow-up.

Baseline renal dysfunction was associated with postoperative improvement of eGFR

In patients with baseline renal dysfunction (CKD stage 3–5, $N=26$), the eGFR significantly improved at the last follow-up compared to the baseline (median: post, $49.0 \text{ mL}/\text{min}/1.73 \text{ m}^2$ vs. pre, $47.9 \text{ mL}/\text{min}/1.73 \text{ m}^2$, $P=0.02$).

On the contrary, the eGFR significantly reduced at the last follow-up compared to the baseline (median: post, $71.3 \text{ mL}/\text{min}/1.73 \text{ m}^2$ vs. pre, $75.4 \text{ mL}/\text{min}/1.73 \text{ m}^2$, $P=0.02$) in patients without baseline renal dysfunction (CKD stage 1–2, $N=35$).

The anti-refluxing procedure and SK type were independent of renal function outcomes

Vesicoureteral reflux (VUR) was a concern in clinical application. Nineteen cases (31.15%, 19/61) underwent an anti-refluxing procedure. There were no significant

differences in eGFR at the last follow-up compared to the baseline, both in patients with (median: 64.66 vs. $57.93 \text{ mL}/\text{min}/1.73 \text{ m}^2$, $P=0.63$) or without (median: 66.39 vs. $68.34 \text{ mL}/\text{min}/1.73 \text{ m}^2$, $P=0.69$) an anti-refluxing procedure.

We also concluded that there were no statistically significant differences in eGFR between the last follow-up and baseline both in CSK (median: 70.53 vs. $75.14 \text{ mL}/\text{min}/1.73 \text{ m}^2$, $P=0.58$) and ASK (median: 60.83 vs. $61.08 \text{ mL}/\text{min}/1.73 \text{ m}^2$, $P=0.83$).

Hypertension was associated with postoperative blood pressure reduction

We compared blood pressure before surgery and at the last follow-up. It revealed a significant reduction in systolic pressure at the follow-up (median: post, 123 mmHg vs. pre, 125 mmHg, $P=0.002$). Notably, in patients with a history of hypertension, a significant reduction in systolic pressure at the follow-up was observed (median: post, 133 mmHg vs. pre, 150 mmHg, $P=0.002$). However, in patients without a history of hypertension, the systolic pressures between follow-up and baseline were comparable (median: post, 120 mmHg vs. pre, 120 mmHg, $P=0.33$).

We also identified 13 (21.31%, 13/61) patients with ‘blood pressure reduction’, with a reduction in systolic pressure more than 20 mmHg and diastolic pressure more than 15 mmHg at follow-up, all of whom had a history of hypertension before surgery. Moreover, we also observed that higher preoperative systolic pressure correlated with more systolic pressure reduction at follow-up by Spearman’s rank test ($P < 0.001$).

Discussion

Key findings

Our cohort initially compared the surgical success, renal function, and blood pressure outcomes among SK patients after ureteral reconstruction surgeries. Here, we found that ureteral reconstruction surgery could preserve renal function, measured by eGFR in SK patients, regardless of the anti-refluxing procedure or the type of SK. Furthermore, we noted a high success rate and a significant decrease in systolic pressure after ureteral reconstruction surgeries.

Strengths and limitations

This study has several strengths. We provided our

experience, renal function outcomes, and blood pressure in the approximately 1-year period after ureteral reconstruction in the SK population, which is essential and beneficial for clinical decision-making. Our data also validated the feasibility of six types of ureteral reconstruction techniques.

There were also some limitations. First, the heterogeneity of cases and surgeries might be problematic due to its retrospective nature. Second, the study was symptom-based rather than based on functional studies. Finally, the sample size was relatively modest due to the disease state being relatively rare.

Comparison with similar research

The main goal of the urologic reconstructive procedure is to preserve or to improve the kidney function. Research showed that the Yang-Monti Ileal ureter is durable and effective in enhancing kidney function with few complications in kidney function loss and SK, as evidenced by long-term renal function outcomes (14). The previous studies confirmed that renal function generally remained stable after ureter reimplantation surgeries (15,16). Another study assessed the long-term functional outcomes of 62 SK patients after pyeloplasty, revealing that pyeloplasty preserved renal function in 90.4% of the SK patients (8).

Explanations of findings

This study indicates that preservation of kidney function was achieved in patients with reconstructive procedures, consistent with other investigators' findings, implying that surgery's primary objective should be to preserve renal function and relieve symptoms.

Moreover, the surgical procedure for SK patients in need of ureteral reconstructive surgeries is highly technically demanding, and preservation of renal function outcomes is crucial. Our team has developed several novel ureteral reconstructive procedures, such as robot-assisted LMG (17) and MLP (18), which has high success rates, fewer postoperative complications, and minimal injury allowing for renal function recovery in SK patients (19,20).

The previous study confirmed that relieving obstruction cures hypertension in the majority of cases, indicating that surgical treatment of urinary tract obstruction can reduce blood pressure (10). Additionally, several studies had previously demonstrated that hydronephrosis can

cause hypertension in animals and in patients, which was attenuated by surgically relieving the obstruction (10,12). In this paper, it seemed that reconstruction surgery may aid in blood pressure control in SK patients, particularly in those who had a history of hypertension.

VUR may be associated with renal dysplasia and could lead to reflux nephropathy (21,22). Kim and his colleagues stated that the anti-reflux technique in laparoscopic ureteral reconstruction reduces *de-novo* VUR development (23). However, the anti-refluxing procedure is still controversial. Here, there were no differences in the eGFR observed at follow-up regardless of an anti-reflux procedure. Therefore, the necessity of anti-refluxing procedure during ureteral reconstruction surgeries in SK, still needs to be interpreted with caution.

As for the relationship between SK type and renal function outcomes, the conclusions from available studies are discrepant. The current study identified that renal injury is even more risky in ASK than CSK (24). However, a previous report stated renal function recoverability was better in ASK than in CSK (8). Interestingly, our results suggested that the type of SK has no bearing on renal function outcomes, which needed further study.

Implications and actions needed

Ureteral reconstruction surgery might be a treatment option to preserve renal function in SK patients. A prospective cohort with a larger sample size is required in the future.

Conclusions

Our data suggested that ureteral reconstruction surgery is feasible and safe in SK patients, which could preserve renal function for at least three postoperative months and achieve a high success rate. Moreover, ureteral reconstruction surgery could reduce systolic pressure. In summary, this study was a preliminary experience to estimate renal function and blood pressure outcomes in SK patients after ureteral reconstruction surgery, which might provide a reference for an appropriate treatment strategy.

Acknowledgments

The authors would like to thank the medical staff who participated in this study.

Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at <https://tau.amegroups.com/article/view/10.21037/tau-24-82/rc>

Data Sharing Statement: Available at <https://tau.amegroups.com/article/view/10.21037/tau-24-82/dss>

Peer Review File: Available at <https://tau.amegroups.com/article/view/10.21037/tau-24-82/prf>

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://tau.amegroups.com/article/view/10.21037/tau-24-82/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was approved by Ethics Committee of Peking University First Hospital (No. 2019-134). Beijing Tsinghua Changgung Hospital, Beijing Friendship Hospital, Beijing Jianguo Hospital, Emergency General Hospital were also informed and approved the study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was obtained from all subjects or their legal guardians.

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Cite this article as: Zuo W, Liu Y, Guan B, Li Z, Zhao F, Wang X, Zhu H, Zhang P, Zhao Z, Zhang G, Zhou L, Li X. Renal function after ureteral reconstruction surgery in patients with solitary kidney. *Transl Androl Urol* 2024;13(6):940-948. doi: 10.21037/tau-24-82