Original Article - Robotics/Laparoscopy
Investig Clin Urol 2023;64:154-160.
https://doi.org/10.4111/icu.20220364
pISSN 2466-0493 • eISSN 2466-054X

INVESTIGATIVE AND CLINICAL UROLOGY
ICUROLOGY

Robotic ureter reconstruction using the native ureter to treat long-segment ureteral stricture of the transplant kidney utilizing Indocyanine green: The first Korean experience

Jinu Kim[1], Seok Jeong Yang[2], Deok Gie Kim[3], Woong Kyu Han[1], Joon Chae Na[1]
[1]Department of Urology, Yonsei University College of Medicine, Urological Science Institute, Seoul, [2]Department of Surgery, Yonsei University College of Medicine, Yongin Severance Hospital, Yongin, [3]Department of Surgery, Yonsei University Wonju College of Medicine, Wonju, Korea

Purpose: Ureteral strictures are a common complication after kidney transplantation. Open reconstruction is preferred for long-segment ureteral strictures that cannot be resolved endoscopically; however, it is known to have the potential to fail. We report 2 successful cases of robotic reconstruction surgery of a transplant ureter using the native ureter with the aid of intraoperative Indocyanine green (ICG).
Materials and Methods: Patients were placed in semi-lateral position. Using Da Vinci Xi, the transplant ureter was dissected, and the stricture site was identified. End-to-side anastomosis of the native ureter to the transplant ureter was performed. ICG was utilized to identify the course of the transplant ureter and confirm the vascularity of the native ureter.
Results: Case 1: A 55-year-old female underwent renal transplantation at another hospital. She had recurrent febrile urinary tract infections (UTIs) and a ureteral stricture requiring percutaneous nephrostomy (PCN). The PCN and ureteral stent were removed successfully after surgery. The patient had only 1 febrile UTI episode after surgery. Case 2: A 56-year-old female underwent renal transplantation at another hospital. She had acute pyelonephritis 1-month post-transplantation, and a long-segment ureteral stricture was identified. She developed a UTI with anastomosis site leakage in the early postoperative period, which resolved with conservative treatment. The PCN and ureteral stent were removed 6 weeks after surgery.
Conclusions: Robotic surgery for managing long-segment ureteral stricture after kidney transplantation is safe and feasible. The use of ICG during surgery to identify the ureter course and its viability can improve the success.

Keywords: Kidney transplantation; Robotic surgical procedures; Ureter

INTRODUCTION

Kidney transplantation (KT) is the treatment of choice for patients with end-stage renal disease (ESRD) [1]. Compared with dialysis, KT provides improved 5-year survival rates (85.5% vs. 35.8%) and quality of life [2,3]. Although KT has these benefits, it also has several potential complications, including graft rejection and failure, infection, and surgical

Received: 7 November, 2022 • **Revised:** 5 January, 2023 • **Accepted:** 7 February, 2023 • **Published online:** 2 March, 2023
Corresponding Author: Joon Chae Na https://orcid.org/0000-0003-4449-8472
Department of Urology, Yonsei University College of Medicine, Urological Science Institute, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
TEL: +82-2-2228-2310, FAX: +82-2-312-2538, E-mail: urona@yuhs.ac

complications. A number of articles reported surgical complication rates after KT ranging from 3% to 14% [4].

Ureteral fistulae (also known as urinary leakage) are an early complication of KT and may lead to graft loss or patient death [4]. Ischemic damage of the ureter is the most common cause of these fistulae. Treatment of ureteral fistulae involves secondary ureteroneocystostomy or end-to-end anastomosis. Ureteral stricture of the transplant ureter is another well-known complication of KT. In contrast to the ureteral fistulae, ureteral strictures are considered as a delayed complication [5]. The etiology of ureteral strictures is not well established, but some studies suggest that multiple renal arteries and donor age older than 65 years increase the risk of ureteral obstruction [6,7]. A longer ischemic time during KT may also be associated with ureteral stricture development. The type of ureter reimplantation technique during KT, such as the Lich–Gregoir or Politano–Leadbetter procedure, does not related to a risk factor for ureteral stricture [8]. These ureteral strictures can lead to impaired graft function if not promptly treated.

Although there are no clear guidelines regarding the management of ureteral strictures in transplant kidneys, endoscopic management is generally considered as the first-line treatment for short ureteral strictures [9]. With the development of endoscopic instruments and techniques, many patients have benefited from simple endoscopic management instead of high-risk open revision surgery [10]. However, when the length of stricture is long, open ureteral reconstruction surgery is required instead of endoscopic management. It is known that open revision surgery is technically challenging because of severe adhesions around the bladder and difficulties with identifying the transplant kidney. The success rate of open revision surgery is 92%, with a complication rate of 16% [11].

Robotic systems provide better surgical outcomes and less postoperative pain compared to conventional open or laparoscopic surgery. However, reports of robotic reconstruction surgery for ureteral strictures in transplant kidneys are limited. The previous reports have mainly focused on manipulating the bladder to manage ureteral strictures, such as creating a Boari flap or performing ureteroneocystostomy [12]. However, in patients with a contracted bladder after prolonged dialysis, there are limitations to using the bladder for reconstruction. Herein, we report 2 cases of robotic reconstruction surgery using the native ureter to correct long-segment ureteral strictures after KT.

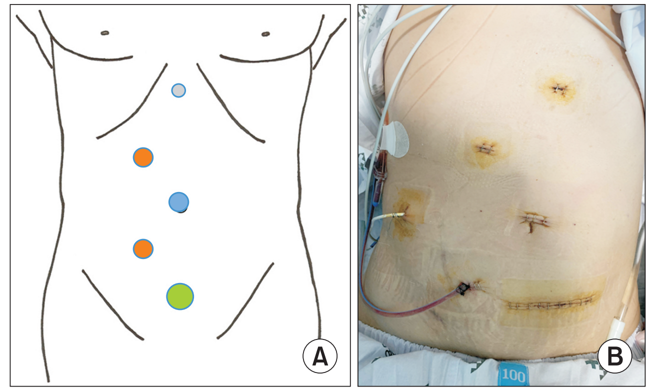

Fig. 1. (A) Diagram of port placement. Blue, camera port; orange, 8-mm robotic port; green, 12-mm port for the surgical assistant; grey, 5-mm port for liver traction and the surgical assistant. (B) Postoperative wounds.

MATERIALS AND METHODS

1. Surgical technique

This study was approved by the Institutional Review Board of the Yonsei University College of Medicine (IRB no. 2022-0331-001). All the study protocols were performed in accordance with the principles of the Declaration of Helsinki. Written informed patient consent was waived owing to the retrospective nature of study. The patients were placed in a semi-lateral position similar to the position used for robotic nephrectomy. Pneumoperitoneum was established using the Veress needle technique. The port configuration is shown in Fig. 1. All ports were inserted under direct vision using a laparoscopic camera. The Da Vinci Xi system was docked after port insertion. The 12-mm trocar for the surgical assistant in the lower abdomen was used as a port for robotic instruments (using the piggy-back method) when an additional robotic arm was required [13]. In this situation, the 5-mm trocar in the subxyphoid area for liver traction was used as a port for the surgical assistant.

After docking the robot, the transplant ureter was dissected, and the stricture site was identified. Nephrectomy of the right native kidney was performed, and the native ureter was harvested. After trimming the native ureter to the appropriate length, the native ureter was attached to the transplant ureter by end-to-side anastomosis. Interrupted suture with 4-0 Vicryl was used for the anastomosis, and a double J ureteral stent was inserted.

2. Use of Indocyanine green

Indocyanine green (ICG) was applied in 2 ways. First, ICG was injected through a percutaneous nephrostomy (PCN) which was previously placed in the transplant kidney. This

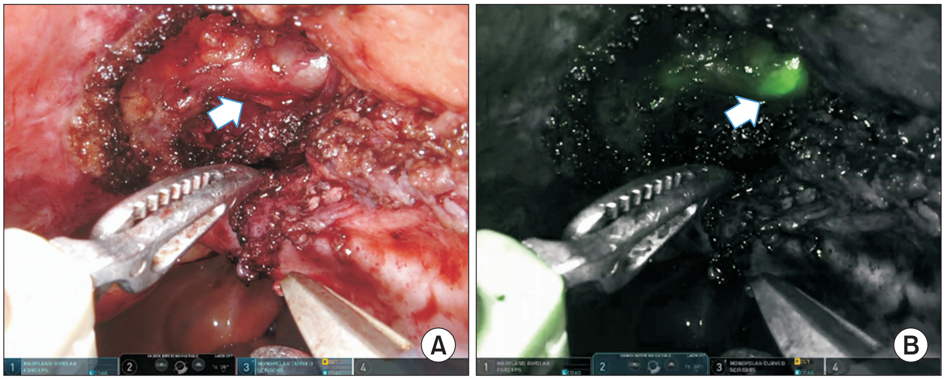

Fig. 2. The transplanted ureter is identified by Indocyanine green injected through the percutaneous nephrostomy tube. The dissected transplant ureter (arrow) is seen on direct visualization (A) and fluorescence imaging (B).

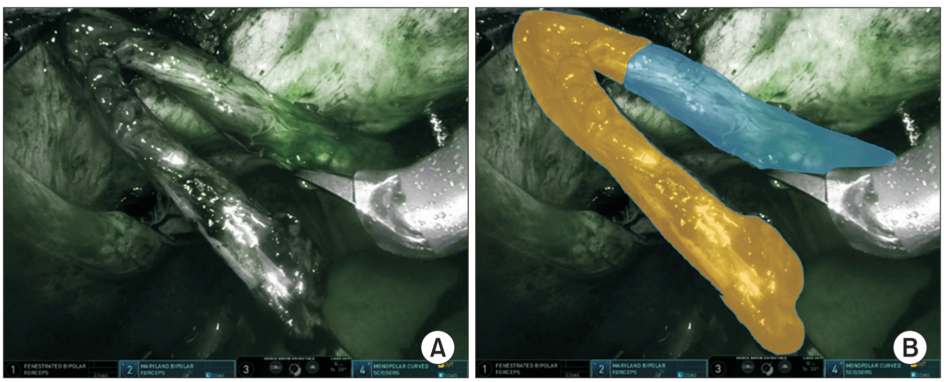

Fig. 3. Intravenous Indocyanine green is used to confirm the vascularity of the dissected native ureter. (A) Dissected native ureter on fluorescence imaging after intravenous Indocyanine green injection. (B) Color representation of the imaging results, with blue portion reflecting a segment with a strong signal and good vascularity and gold portion reflecting a segment with a weak signal and poor vascularity which was trimmed before anastomosis.

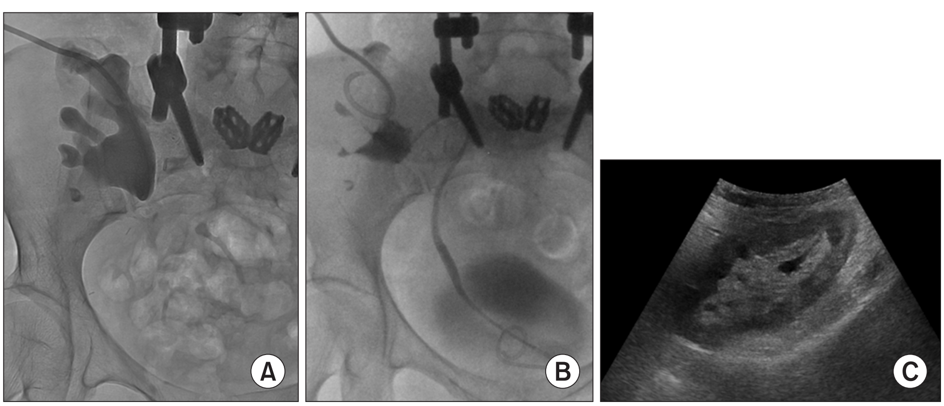

Fig. 4. Case 1. Antegrade pyelography images before surgery (A) and 2 weeks after surgery (B). (C) Sonography of the transplant kidney at 4-month follow-up showed no sign of hydronephrosis.

procedure enables to identify the course of the transplant ureter (Fig. 2). Second, ICG was injected intravenously to confirm the vascularity of the dissected native ureter. A weak ICG signal area indicates a low vascularity of the ureter, which should be excised prior to anastomosis (Fig. 3).

RESULTS

1. Case 1

A 55-year-old female underwent deceased donor KT (DDKT) at an outside hospital. She developed ureteral stricture of the transplant kidney, which was managed with PCN placement 5 months after transplantation. She also had recurrent febrile urinary tract infections (UTIs) and was referred to our hospital 16 months after KT. At that time, her serum creatinine was 3.01 mg/dL. Preoperative antegrade pyelography showed total obstruction of the transplanted ureter. The length of stricture was 8.5 cm (Fig. 4). The goals of the surgery were to remove the PCN and prevent further UTI episodes, despite the possibility of graft failure progression.

ICG injected through the PCN was unable to identify the renal pelvis, because of thickening of the renal pelvis wall probably caused by recurrent episodes of UTI. Subsequent instillation of normal saline through the PCN revealed a dilated renal pelvis on intraoperative sonography.

https://doi.org/10.4111/icu.20220364

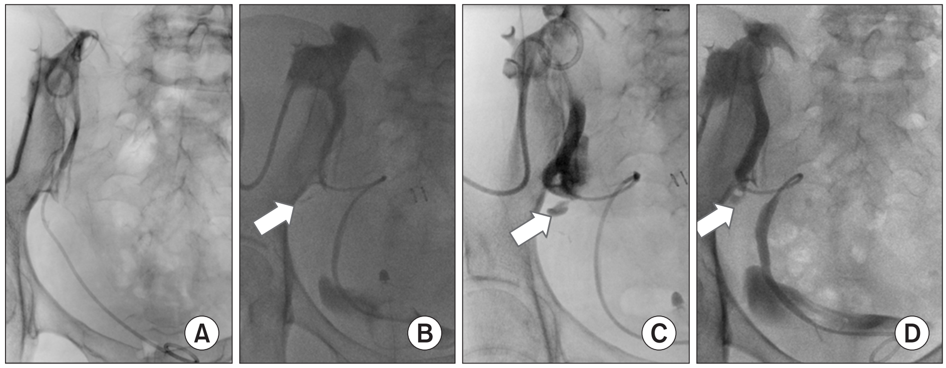

Fig. 5. Case 2. Antegrade pyelography images before surgery (A) and 6 days after surgery (B). Initially, the anastomosis site was intact (arrow). (C) Leakage of the anastomosis site occurred (arrow) when the patient developed a carbapenem-resistant urinary tract infection, as seen on the 10-day postoperative antegrade pyelography image. (D) The leakage healed with conservative treatment, as shown on the 6-week postoperative image. The tail-like contrast-filled structure is the remnant transplant ureter distal to the anastomosis site (arrow).

Needle puncture was performed to confirm the location of the renal pelvis of the transplant kidney. Pelvico-ureteral anastomosis was performed and test irrigation of the renal pelvis through the PCN confirmed the absence of anastomosis site leakage.

The PCN was removed 2 weeks later, and the ureteral stent was removed 1 month after surgery. The patient had 1 episode of febrile UTI during the first 3 months after surgery but none since. Her serum creatinine 1 year after surgery was 2.42 mg/dL (Fig. 4).

2. Case 2

A 56-year-old female underwent DDKT at an outside hospital and developed acute pyelonephritis 1 month after transplantation. A long-segment ureteral stricture was detected, which was managed with PCN placement. The patient was referred to our hospital 3 months after KT for ureteral reconstruction. Her serum creatinine was 1.20 mg/dL at that time. Antegrade pyelography identified a ureteral stricture 4.8 cm in length (Fig. 5). Because of the long length of this stricture, robotic reconstruction surgery using the native ureter was performed rather than endoscopic surgery or open ureteroneocystostomy.

Despite preoperative prophylaxis with broad-spectrum antibiotics, the patient developed a carbapenem-resistant *Klebsiella pneumoniae* UTI immediately after the surgery, with concomitant leakage at the anastomosis site. The leakage resolved after conservative management. The PCN and ureteral stent were removed 6 weeks after surgery. The patient's serum creatinine was 1.31 mg/dL at her 9-month follow-up visit (Fig. 5).

DISCUSSION

We report 2 cases of robotic reconstruction surgery using the native ureter in long-segment ureteral strictures after KT. The use of intraoperative ICG can aid increase the success rate of this procedure compared to open surgery. Antegrade injection of ICG to the collecting system can aid in identification of the transplant ureter which is challenging due to severe adhesion and lack of anatomical landmarks. Moreover, intravenous injection of ICG can reveal the vascularity of the native ureter when planning the proper anastomosis site. The native ureter is anticipated to lose its blood supply after dissection from its surrounding structure to reach to the point of anastomosis. We found that the ureter which appeared to be viable in the naked eye was not a truly viable ureter upon injection of ICG and additional trimming was required in both cases.

Ureteral strictures have been reported in 2.6%–15% of patients after KT and are the most common long-term urologic complication. In their study of 1,787 patients, Karam et al. [6] identified 74 patients (4.1%) who developed a ureteral stricture after KT. The mean time of stricture occurrence was 5.4 months after transplantation, and the presence of more than 2 renal arteries was a risk factor for stricture formation ($p=0.009$). There was no significant difference in rate of ureteral strictures between patients with or without double J stent insertion. Mah et al. [14] reported ureteral complications in 1,072 patients who underwent KT with different types of donor kidneys: 494 kidneys were donated after circulatory death, 305 were donated after brain death, and 273 were received from a living donor. The risk of ureteral complications was similar in patients who received living donor and donation after brain death kidneys (hazard ratio [HR], 0.46; 95% confidence interval [CI], 0.16–1.35;

p=0.160), but the risk was higher in patients who received a kidney donated after circulatory death than in those receiving a kidney donated after brain death (HR, 2.77; 95% CI, 1.05–7.31; p=0.040).

Since the introduction of endoscopic treatments in the early 1980s, endoscopic techniques have been commonly used for the management of ureteral strictures. Frequently performed procedures include balloon dilation or endoureterotomy using cold knife or holmium laser [15]. The most commonly reported endoscopic treatment is antegrade or retrograde balloon dilation to the ureter. The success rate of balloon dilation is 51% for the first treatment but decreases to 25% on the second attempt [16-18]. Kristo et al. [19] reported the results of 9 patients with short ureteral strictures managed by balloon dilation with or without holmium laser endoureterotomy. The mean stricture length was 0.28 cm (0.25–0.5 cm). No postoperative complications were observed during a median follow-up period of 24 months. For short ureteral strictures less than 0.5 cm, endoscopic treatment may be considered as the first-choice of treatment.

Open revision surgery is considered for long ureteral strictures or strictures that have failed endoscopic treatment. If the ureteral stricture length is short or if the bladder capacity is abundant, the bladder can be used to perform ureteroneocystostomy, pyelovesicostomy or Boari flap after removing the stricture segment. However, contraction of the bladder is commonly seen in patients with ESRD after a prolonged duration of dialysis. When the size of the bladder is not available to reach the graft ureter or renal pelvis, the native ureter is used to perform a ureteroureterostomy or pyeloureterostomy to the graft kidney. In a study reported by Salomon et al. [20], 19 of 570 patients (3.3%) who developed urologic complications after KT underwent open pyeloureterostomy with the native ureter. The reported complications after KT were 10 cases (1.7%) of ureteral stenosis, 6 cases (1.1%) of urinary leakage, and 3 cases (0.5%) of vesicoureteral reflux. The surgery involved cutting and mobilizing the native ureter 3–4 cm above the iliac vessels and anastomosis of ureter to the renal pelvis of the transplant kidney. No further ureteral complications occurred after surgery. Schult et al. [21] reported 48 patients who underwent open pyeloureterostomy with the native ureter after KT for ureteral stricture, necrosis, or bleeding. Six patients (12.5%) developed complications after surgery, including 4 cases of anastomosis site leakage and 2 cases of stenosis of the native ureter. Two of the 4 patients with urinary leakage underwent additional revision surgery. Other complications, such as sepsis, pyelonecrosis, and acute graft rejection, were also reported. In a study reported by Decurtins et al. [22], 7 of 25 patients (28.0%) who underwent open secondary pyeloureterostomy for ureteral necrosis developed urologic complications, including 4 cases of anastomosis site leakage and 3 cases of ureteral stenosis. Three of the 4 urinary leakage cases (75.0%) resolved with nephrostomy catheter insertion, whereas 1 required additional surgery for redo-anastomosis. Of the 3 stenosis cases, 2 (66.6%) were managed with temporary ureteral stent insertion, and 1 was treated with pyeloureterostomy using the contralateral ureter.

The benefits of robotic surgical systems are well established. A few previous reports described the management of long-segment transplant ureteral strictures using robotic systems. Abdul-Muhsin et al. [9] reported 5 patients who underwent robotic reconstruction surgery for transplant ureteral strictures after failed endoscopic treatment. The patients were placed in the lithotomy position, with port placement similar to that used for robotic radical prostatectomy. The reconstruction technique was pyelovesicostomy with a Boari flap in 2 patients and the Lich–Gregoir reimplantation technique in 3 patients. A Foley catheter was maintained for 7–14 days. The authors found no early or delayed urinary leakage. Kim et al. [12] also reported the results of reconstruction using a robotic system in 5 patients with long transplant ureteral strictures. Their mean stricture length was 2.5 cm. Port placement was similar to that used for robotic radical prostatectomy, and the procedure was pyelovesicostomy in 3 patients and ureteroneocystostomy in 2 patients. Three techniques were used to identify the transplant kidney and ureter: instillation of normal saline through the nephrostomy tube, injection of ICG through the nephrostomy tube, or direct visualization using a flexible ureteroscope. No patient required hospital readmission during the first 30 days after surgery.

Robotic surgery for ureteral reconstruction using the native ureter has been performed less commonly. Benamran et al. [23] described robot-assisted ureteral reconstruction surgery using the native ureter in 10 patients. A ureteral catheter was inserted at the beginning of surgery to distinguish the native ureter from the graft ureter. Uretero-ureteral or ureteropyelic anastomosis was performed. 4 patients required conversion to open surgery because of severe fibrosis around the graft kidney (2 patients) or failure to identify the graft ureter (2 patients). These authors discussed the difficulties of identifying graft kidneys and ureters because they were usually covered by thick fibrotic tissue.

Although open pyeloureterostomy or ureteroureterostomy using the native ureter has been commonly used as a salvage operation to treat ureteral complications after KT, it is a procedure known to have possibility of failure. Consid-

 https://doi.org/10.4111/icu.20220364

ering that anastomosis of the ureter-ureter or ureter-renal pelvis is nearly a fail-free procedure when operated for various causes such as iatrogenic injury during gynecological or colorectal surgery, it seems unusual that the same procedure applied on a transplant ureter or renal pelvis can result in anastomosis site leakage or stenosis. One of the causes may come from the graft versus host immunologic reaction between the transplant ureter/renal pelvis and the native ureter. The maintenance of immunosuppressants may also impair wound healing. These are factors which are not easily controllable by the surgeon. The authors speculated that the vascularity of the anastomosis site may be a crucial factor leading to anastomosis site leakage or stenosis, and hypothesized that intraoperative ICG can confirm the vascularity of the native ureter to be used. In both cases we found that although the native ureter seems to be pinkish and viable to the naked eye it was not true on injection of ICG and additional trimming of the native ureter was required while taking caution to maintain adequate length for a tension free anastomosis.

Using the native ureter for KT ureter reconstruction has been described by Benamran et al. [23]. However, they reported a high rate of open conversion of 40%. Salvage operation after KT is a difficult procedure as there is no anatomical landmark to identify the artery, vein and ureter of the transplant kidney. Even after thorough review of the imaging study the typically severe anastomosis of the surrounding tissues makes the procedure difficult. The authors have utilized antegrade injection of ICG through a preplaced PCN to facilitate identification of the transplant ureter. During the second case initial investigation of the expected area failed to reveal the ureter. However, after administration of ICG we found that the ureter was only 1–2 cm away from the previous dissected area. Also using intraoperative sonography can help identify the artery and vein of the graft kidney, and prevent injury of the vessels which can lead to loss of the graft kidney.

Our method also differs in the port placement with previous reports. In most reports, patients were placed in the lithotomy position combined with Trendelenburg position, whereas we placed patients in a semi-lateral position. The lithotomy position is more suitable to approach the ureterovesical junction and lower ureter, and should be chosen if reconstruction using the bladder such as ureteroneocystostomy or pelvicovesicostomy is considered. However, the semi-lateral position is more suitable to approach the graft kidney and pelvic area as it facilitates exposure by dropping the bowels in the contralateral direction as in our case. Also, in our cases nephrectomy of the native kidney was planned, which can be done in the semi-lateral position without changing the position of the patient. The semi-lateral position is also known to be associated with less cardiopulmonary impairment than the lithotomy/Trendelenburg position [24].

The native ureter can be used to perform ureteroureterostomy or ureteropyelostomy to the graft kidney when urologic complication occurs after KT. It should especially be considered if the ureter stricture segment is long or if the bladder is contracted and cannot be used for reconstruction. The presence of the ipsilateral native ureter should be checked before planning surgery, as patients with ESRD often undergo nephrectomy for various reasons. However, the procedure is known to have a complication rate ranging from 0%–28%. It is challenging as it is hard to identify the target anatomy because there is no anatomical landmark to identify the graft ureter and is normally associated with severe adhesion and surrounded with dense fibrotic tissues. The native ureter is often contracted after prolonged ESRD and its narrow diameter requires fine handling during anastomosis. Using the robot can make the procedure more feasible as it provides a magnified 3D vision and fine handling of instruments. In this study we suggest that the success rate can also be improved by utilizing ICG when finding the native ureter and also confirming vascularity of the anastomosis site. Although our cases were successful further experience with more patients is required.

CONCLUSIONS

In this report, we described 2 patients who underwent robotic surgery using the native ureter for reconstruction of a long-segment ureteral stricture in the transplanted kidney. While our general technique has been widely used during open surgery it is a procedure known to have a risk of failure. Also, while it can be reproduced by robotic surgery, it has been reported to have a high rate of open conversion. We propose that using the robotic system and utilizing ICG can increase the success rate of anastomosis and decrease the rate of open conversion. Further studies and a larger number of cases is needed to confirm our speculation.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

FUNDING

None.

AUTHORS' CONTRIBUTIONS

Research conception and design: Jinu Kim and Joon Chae Na. Data acquisition: Joon Chae Na, Seok Jeong Yang, and Deok Gie Kim. Data analysis and interpretation: Jinu Kim and Joon Chae Na. Drafting of the manuscript: Jinu Kim. Critical revision of the manuscript: Joon Chae Na. Administrative, technical, or material support: Joon Chae Na. Supervision: Woong Kyu Han and Joon Chae Na. Approval of the final manuscript: all authors.

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