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Robotic-assisted Kidney Transplantation With Simultaneous Bilateral Nephrectomies Is an Efficient, Feasible, and Safe Way to Manage Patients With Renal Failure Secondary to Adult Polycystic Kidney Disease

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Abstract. Kidney transplantation has become the standard of care for end-stage renal disease secondary to adult polycystic kidney disease. Open surgical techniques remain the gold standard, although minimally invasive methods have gained traction in recent years. Native nephrectomy is frequently needed secondary to size or symptoms. Continued developments in surgical technology have allowed for the introduction of computer-assisted surgery (Robotics). We aim to describe the feasibility, safety, and efficiency of simultaneous laparoscopic bilateral nephrectomy and robotic-assisted kidney transplantation to treat end-stage renal kidney transplantation secondary to polycystic kidney disease. In this initial experience, 3 patients underwent kidney transplantation with a simultaneous bilateral nephrectomy. All patients tolerated the procedure well with no postoperative blood transfusions, dialysis, or surgical site infections. Simultaneous laparoscopic bilateral nephrectomy and robotic-assisted kidney transplantation may be feasible, safe, and efficient techniques. Complications were minimal, with short hospital stays.

Supplemental Video; <http://links.lww.com/TXD/A352>

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INTRODUCTION

Since the first successful human kidney allograft transplantation was performed¹ in 1954, numerous and significant developments in transplantations have occurred.

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The surgical technique, however, remained static. Current open techniques initially described have continued to be the standard of care.² In the 1990s, advanced laparoscopy and later robotic systems like the da Vinci surgical system (Intuitive Surgical) were introduced. This expanded the capabilities of performing complex operations, fine dissections, and microsuturing,³ and produced more favorable outcomes.⁴ These new technologies and techniques have brought kidney transplantation closer to completely minimally invasive surgery. The first pure robotic-assisted kidney transplantation (RAKT) was performed in 2010.⁵ Since then, there have been numerous procedural refinements.

In patients with adult polycystic kidney disease (APKD), bilateral nephrectomy is frequently needed. The indications may include the original kidney size, chronic pain, infections, bleeding, and early satiety. Usually, this is achieved in 2 different operations or a single operation that requires extensive incisions with significant morbidities. Most commonly, donors >35 y are examined using imaging, whereas donors <35 y are examined using genetic sequencing. This guideline aids providers in gauging the suitability of donors. Additionally, all suitable transplant patients are then considered for robotic surgery except when vascular disease prohibits clamping using laparoscopic clamps or pelvic adhesions is excessive.

This article’s primary goal is to provide a proof of concept to perform simultaneous laparoscopic bilateral nephrectomy and RAKT. Consistent with the institutional review board approvals, the patients’ data included in this series show that this procedure delivers outstanding outcomes.

CASES

We performed 3 cases as a proof of concept, where in laparoscopic bilateral nephrectomies were followed by RAKT. In this series, nephrectomies were performed to alleviate symptoms. The primary demographics of these patients are listed in Table 1. The patients described in this case series vary in age and symptomology. They represent the typical APKD population undergoing transplantation. Before procedure, all cases had sufficient workup, including preoperative imaging presenting large polycystic kidneys averaging 18 × 11 × 13 cm. Pain and early satiety were indications for our series. Two females and 1 male are included. All donors were living related or unrelated. In all cases, the decision was made to perform bilateral nephrectomies independently. In addition, all live donors chosen had single vessels, which was coincidental. Prior cases have been performed successfully for other indications with multiple vessels.

Our program typically performs a transplant first through a standard lower abdominal incision. The nephrectomies are performed about 3 mo later through a midline laparotomy. Patients consented to the novelty of combining the 2 procedures after thorough discussion regarding the outcomes, risks, and cited research. Additionally, patients were aware of our institution’s advanced knowledge and use of robotics, specifically robotic transplantation. There was no ethics approval required as this procedure included no new surgical codes. Rather, it is a combination of preexisting code.

TECHNIQUE

These operations were managed in a standard perioperative fashion, similar to an open kidney transplant. Similar lines were placed, and all induction immunosuppression was completed early intraoperatively. After induction of general anesthesia, an 18-F Foley 3-way catheter was placed. The patient was placed in a supine position with slight reverse Trendelenburg and a right side uptilt (Figure 1A). A 15-mm trocar was inserted in the periumbilical area, and the abdomen was insufflated using

the standard port placement technique. Additionally, 1 robotic 8 mm trocar and 1 assisting trocar were inserted in the right flank across a straight line at the umbilicus level. A second 5-mm trocar was inserted in the epigastrium (Figure 1B).

The decision in all cases was to perform the right nephrectomy first. The lateral attachments of the colon were divided, and Gerota’s fascia was quickly entered, where we worked to avoid injury to a thinned-out mesocolon (Figure 1C). The lower pole was dissected from lateral to medial until the ureter is identified, dissected, and divided between clips. The inferior vena cava was then identified, and the hilum of the kidney was dissected. We stayed close to the kidney hilum and controlled it using a vascular stapler (Medtronic-Covidien). This aids in avoiding any injuries to the major vessels in an otherwise distorted hilum. The upper pole was dissected using Ligature (Medtronic-Covidien), followed by freeing the attachments. Throughout this dissection, numerous cysts were drained using a combined electrocautery/suction/irrigation device (Probe Plus II, Ethicon). This device allows for maximum suction, which helps prevent most intrabdominal spillage and allows the kidney to be easier to mobilize. The kidney was then placed in a large endocatch bag and extracted from the midline trocar. We morselized the kidneys inside the bag, allowing easier removal from a small incision and avoiding major spillage. The incision is extended slightly to the full 4–5 cm. The trocar was then replaced by a GelPort Laparoscopic System (Applied Medical). The 15-mm trocar was placed through the port. Two robotic trocars were placed on the left side, umbilicus level (Figure 1D). The operating table was repositioned with a left side uptilt. The left kidney was dissected similarly, starting with the lower pole and ureter, followed by the hilum and upper pole. The kidney again was placed in an Endocatch bag and morselized.

A standard robotic transplant procedure was then followed. This generally followed the steps described by Rajesh Ahlawat’s most recent paper.⁶ At this point, all robotic trocars are used. We then added an AirSeal insufflation management system (CONMED) and robotic trocar through the GelPort. The 15-mm trocar was replaced. The table is placed in a reverse Trendelenburg position with no tilt. The robot was docked and targeted toward the right lower quadrant (Figure 2A). A straight longitudinal incision was made on top of the iliac artery, and the external iliac artery and vein were dissected circumferentially (Figure 2B). A transverse incision across the peritoneum was performed to make a pocket for the kidney to be later retroperitonealized. The bladder was then filled with 200 mL of irrigation fluid. The peritoneum and detrusor muscle layers were dissected, and the mucosa was opened. We then placed a 4.0 vicryl stitch toward the distal end of a future ureteric anastomosis. A total of 3 Scanlan Reliance Bulldog Clamps (Scanlan International) were placed in the abdomen. Ice was placed inside the abdomen through the GelPort. The kidney was also wrapped tightly in gauze and ice and inserted into the abdomen; we then closed the GelPort. The external iliac vein was clamped first, and a venotomy was performed using curved scissors. We inserted a 5.0 PTFE stitch cut to 20 cm and performed an end-to-side anastomosis (Figure 2C).

We then used the third Bulldog clamp for the renal vein and recycled the other 2 clamps for the external iliac artery. Robotic potts scissors were used to perform the arteriotomy and curved scissors to make a rounded aperture that matched the renal artery. We inserted a 6.0 PTFE stitch cut to 18 cm to

TABLE 1.
Patient demographics

	Patient no. 1	Patient no. 2	Patient no. 3
Age	50	60	37
Ethnicity	Caucasian	Caucasian	Caucasian
Body mass index, kg/m ²	25.37	25.01	26.5
Gender	Female	Female	Male
Average kidney sizes (L × W × D) cm	17 × 11 × 13	16 × 10 × 10	22 × 13 × 16
ASA physical status ^a	3	3	3
Indication for nephrectomy	PKD	PKD	PKD
Hypertension	Yes	No	Yes
Diabetes	No	No	No

^aAmerican Society of Anesthesiology (ASA) physical status that helps determine a patient’s ability to tolerate surgery and anesthesia.

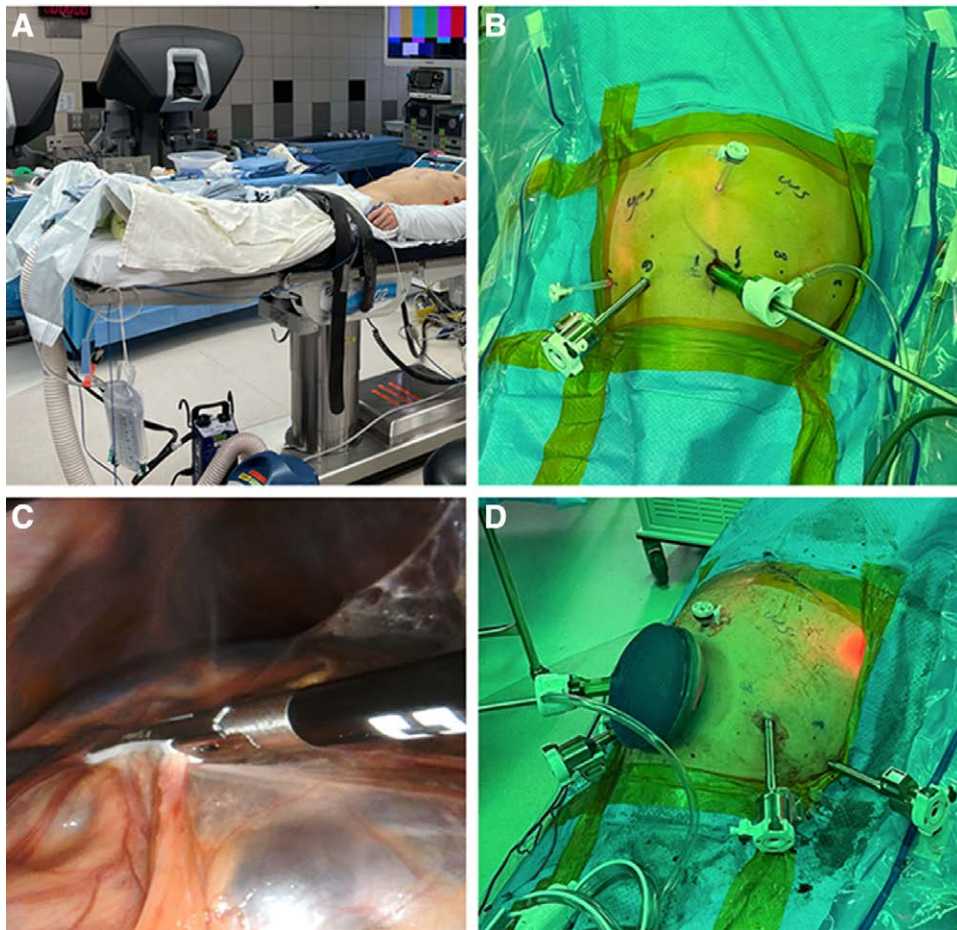


FIGURE 1. A, Patient positioned 3-feet from the anesthesia machine; (B) epigastric trocar placement; (C) removal of the lateral attachments; and (D) robotic trocar placement.

perform the arterial end-to-side anastomosis (Figure 2D). Once completed, the kidney was reperused. Hemostasis around the hilum was achieved using small metal clips. The kidney was placed in the retroperitoneal pocket and closed using the flaps created earlier in the case using a HemoClip (Boston Scientific) and a standard stitch. A small cut was then performed in the undersurface of the ureter, and a 5.0 PDS (Ethicon) was used to do the anastomosis. The previously placed vicryl stitch was used to line the distal end of the anastomosis and later to close the tunnel of the detrusor muscle on top of the ureter. Once the back wall was performed, a 7 × 12 F stent (Olympus America) was placed through the ureter and bladder. Once the mucosa was sutured circumferentially, the detrusor muscle tunnel was closed using the vicryl stitch (Figure 2E). The robotic instruments were removed, the fascia was closed using 0 PDS stitches, and the skin using 4.0 Monocryl at all sites. A drain was placed through the robotic trocars (Figure 3A and B).

RESULTS

Postoperatively, all patients resumed diet and ambulation immediately. Perioperative data are summarized in Table 2. Operative time averaged 439.5min, and average blood loss was 350mL. Organs began to function immediately. The average warm ischemia time was 48min. The average cold ischemia time was 329min because of the sequential nature of 1 case, though our institution's average time is under 2h. All patients were

discharged on postoperative days 2 or 3. No patient required readmission in the early postoperative period. All patients followed the usual pattern of increasing glomerular filtration rate. One patient received a preplanned transfusion during the case as she started with significant anemia at baseline. This delayed the nature of transfusion was in hopes that induction immunosuppression and maintenance would avoid sensitization. Overall, no significant postoperative bleeding was observed. In this series, all patients were discharged either 2 or 3 d postoperatively to their home or a hotel setting for distant patients. Safety could be guaranteed because of our institution's robust, meticulous outpatient monitoring system, including frequent labs, expedited contact with providers, and postoperative visits. This length of hospital stay was equivalent to standard live donors though shorter than expected for this combined procedure.

DISCUSSION

Simultaneous nephrectomy and transplantation have been reported in the past.⁷ Although the outcomes were acceptable, increased hospital stays and needs for blood products were reported. Also, in many of these case series, the ipsilateral kidney was removed, leaving the patient with the second kidney.⁸ The leftover kidney can continue to cause issues and symptoms of cyst rupture, bleeding, and infections. Generally, performing the nephrectomy operation before transplantation is discouraged. This is because the patients become anephric

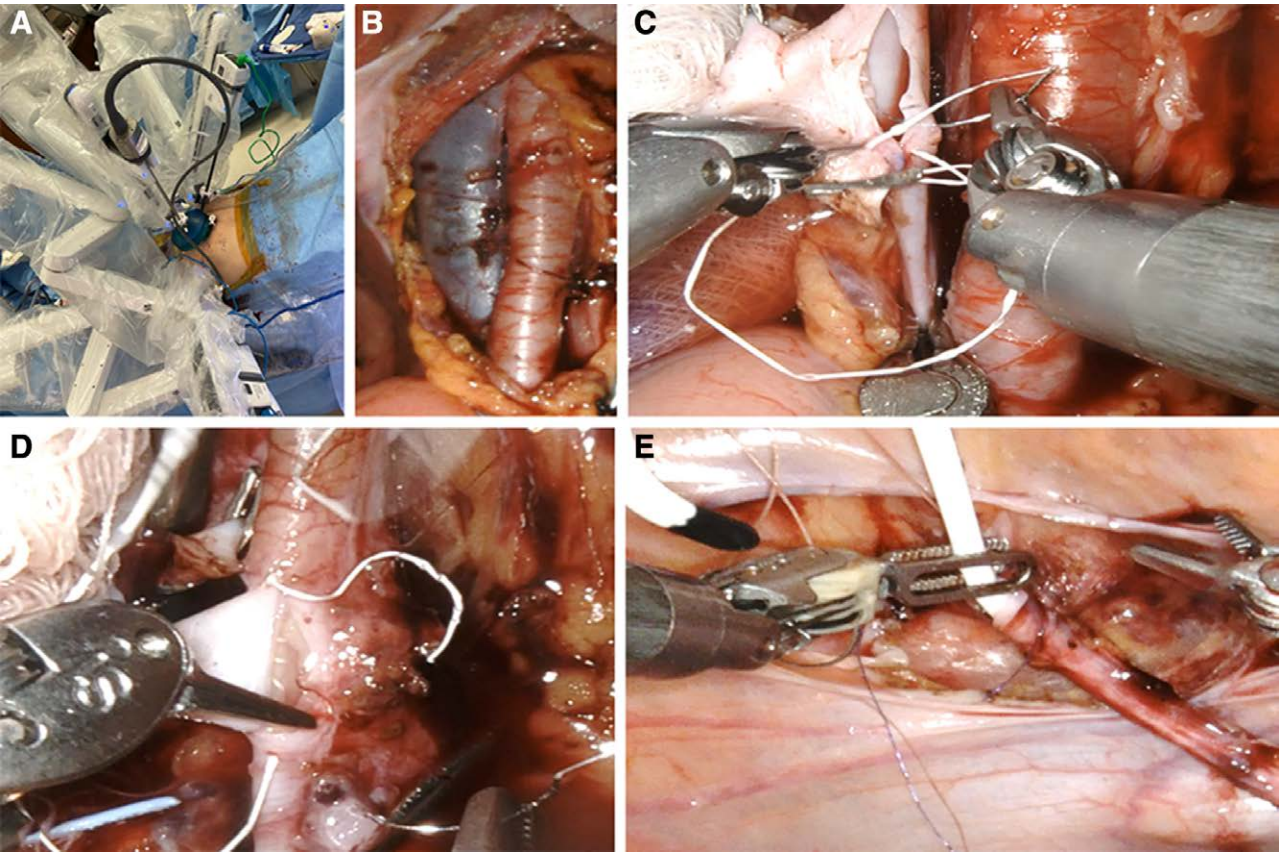


FIGURE 2. A, Trocar positioning for robotic-assisted kidney transplantation; (B) longitudinal view of external iliac artery and vein; (C) external iliac vein venotomy; (D) external iliac artery venotomy; and (E) Vicryl stitch closure of the tunnel of the detrusor muscle.

with more issues regarding anemia and hemodynamics.^{9,10} Also, many of these patients continue to produce urine, which helps in fluid management even when on dialysis. If nephrectomy is performed first, postoperative adhesions can limit options of peritoneal dialysis before the transplant.

Computer-assisted surgery is a new concept in kidney transplantation, and utilization remains limited. This is primarily

due to a lack of training and resources. As noted in Table 3, the Ahlawat Group of Delhi published an extensive series on RAKT outcomes with regional hypothermia.⁶ Their cohort reported excellent outcomes, low risk of complications, and, more importantly, overall feasibility.

Patients with APKD who also need nephrectomies may benefit from a combination of minimally invasive techniques. There are limitations to each technique but combining advanced laparoscopy with current robotic technology may bridge gaps. Standard laparoscopy becomes limited when fine vascular dissection and suturing are needed. On the other hand, current robotic technology can be cumbersome because of the multiple required changes in positioning, like performing bilateral nephrectomies in APKD patients. We exploited the advantages of the 2 techniques, the flexibility of a laparoscopic nephrectomy and precision of robotic

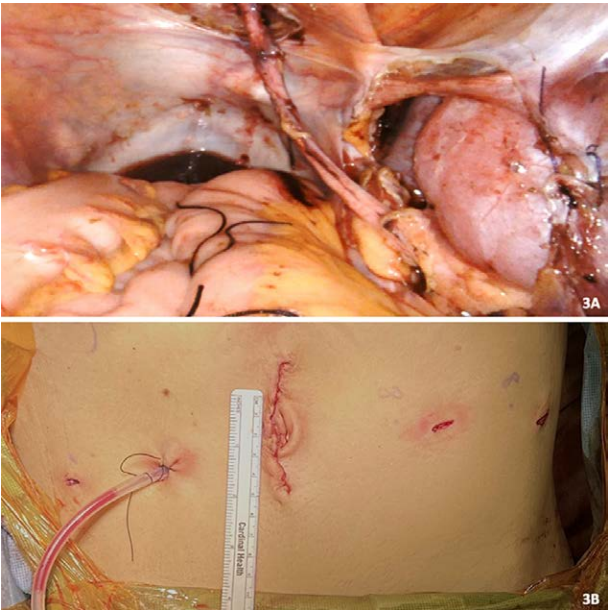


FIGURE 3. A, Final product of robotic-assisted kidney transplantation; (B) final incisions after closure.

TABLE 2.
Perioperative data

	Patient no. 1	Patient no. 2	Patient no. 3
Operating room structure	Parallel	Sequential	Parallel
Actual surgical time, min	387	492	414
Cold ischemia time, min*	452	206	463
Estimated intraoperative blood loss, mL	200	500	50
Intraoperative blood requirements, mL	n/a	500	n/a
Postoperative blood requirements	no	No	no
Postoperative dialysis	no	No	no
Surgical site infection	no	No	no
Length of stay (d)	2	3	3

TABLE 3.
Postoperative outcomes

	Robotic	Open	P ^a
Mean postop on VAS scale 1–10 (SD) ^b			
At 12 h	3.7 (0.7)	4.6 (1)	<0.001
At 24 h	2.2 (1.3)	3.5 (0.7)	<0.001
At 48 h	1.2 (1.3)	1.7 (0.8)	0.025
At 96 h	0.9 (1.1)	1.4 (0.5)	0.068
Mean analgesic use (SD) ^{c,d}			
IV fentanyl (µg)	1291.4 (212.6)	1830.9 (422.3)	<0.001
Epidural-ropivacaine (mg)	0 (0)	69.4 (55.9)	<0.001
PCA morphine (mg)	20.1 (9.5)	31.2 (7.2)	<0.001
No. DGF (%)	0 (0)	9 (2.4)	0.081
No. need for dialysis at any time to latest follow-up (%)	3 (2.4)	18 (4.8)	0.247
Median mg/dL serum creatinine (IQR)			
At time of discharge	1.1 (1–1.3)	1.1 (0.9–1.4)	0.343
At 1 y	1.2 (0.9–1.4)	1.2 (1–1.4)	0.164
At latest follow-up	1.2 (1–1.4)	1.2 (1–1.5)	0.233
No. complications/adverse events (within 6 mo postop) (%)			
Wound infection/dehiscence	0 (0)	15 (4)	0.023
Graft vascular thrombosis/stenosis	0 (0)	3 (0.8)	0.316
Graft torsion	0 (0)	0 (0)	0.999
Urologic (urine leak/stricture)	1 (0.7)	1 (0.3)	0.437
Urinary tract infections	5 (4)	15 (4)	0.999
Acute tubular necrosis	5 (4)	21 (5.6)	0.485
Immunosuppressive drug toxicity	3 (2.4)	4 (1.1)	0.272
Deep vein thrombosis/pulmonary embolism	1 (0.7)	6 (1.5)	0.706
No. graft biopsy (%)	26 (20.6)	89 (23.5)	0.500
No. re-exploration (%)	3 (2.4)	13 (3.4)	0.557
Median d length of stay (IQR) ^e	8 (5–12)	8 (6–14)	0.647

Although the rates of wound complications were significantly different between the 2 study groups in the unadjusted chi-square analysis, adjusted multivariable regression analysis to assess the preventative odds ratio of robotic surgery on wound complications was not feasible as there were 0 events in the robotic arm of the study.

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^aStudent's t-test, Mann-Whitney test, or chi-square test as appropriate.

^bThe visual analog scale, a subjective scale for measuring acute and chronic pain.

^cRegime of IV fentanyl + epidural ropivacaine used for initial 7 patients in robotic group and PCA morphine + IV fentanyl used afterward (in open cases IV fentanyl + epidural ropivacaine was the standard, and in select cases with pain not controlled by 2 drugs IV fentanyl was also added; none of the robotic patients required the 3-drug regime).

^dPatients re-explored were not included.

^eFixed at 8 d for all patients undergoing KT; regardless of the approach, this has been a long-standing practice at the treatment hospital and is part of the treatment package for these patients.

DBF, delayed-graft function; IQR, interquartile range; KT, kidney transplantation; PCA, patient-controlled analgesia.

transplantation, to achieve a final goal of minimally invasive surgery. Compared with what is reported in the literature of open techniques and simultaneous surgery, this series' results show favorably regarding the length of stay in comparison. Although this is only a proof-of-concept series, we did not encounter excessive blood loss or other complications

CONCLUSION

Few advancements in the surgical technique of kidney transplantation have been made over the decades. Combining advanced laparoscopy with computer-assisted surgery can be exploited to perform simultaneous nephrectomy and kidney transplantation in APKD patients. However, it should be noted that the combination of these procedures is better suited for experienced surgical teams who have moved past the significant learning curve associated with robotic surgery. Hopefully, this initial experience will be expanded so that many of these carefully selected patients can avoid multiple surgeries and obtain good outcomes with minimal complications.

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