Retrospective Cohort Study

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Successful robotic kidney transplantation for surgeons with no experience in minimally invasive surgery: a single institution experience

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Background: Robotic kidney transplantation (RKT) is a novel and welcomed innovation yielding good surgical outcomes. However, data on the feasibility and safety of performing RKT by surgeons with a lack of prior minimally invasive surgery (MIS) experience are limited. The authors aimed to evaluate the surgical and functional results of RKT and present the learning curves (LC) of RKT by a single surgeon with no prior experience in MIS.

Materials and methods: This was a retrospective study of all RKT performed between November 2019 and April 2023 at Severance Hospital in Seoul, South Korea. The authors analyzed surgical and functional outcomes, as well as complication rates of RKT in comparison to open kidney transplantation (OKT). The authors evaluated LCs using the cumulative summation method to describe the number of cases associated with the competency of a single surgeon.

Results: A total of 50 patients who underwent RKT and 104 patients who underwent OKT were included in this study. In RKT group, the median surgical console time was 193 min (interquartile range, 172–222) and the median vascular anastomoses time was 38 min (35–44). Total operation time was 323 min (290–371) and rewarming time was 62.5 min (56.0–70.0) in RKT group compared to 210 min (190–239) and 25 min (21–30), respectively, in OKT group. Despite extended surgical durations with a robotic technique, both groups had comparable intraoperative and postoperative outcomes, as well as renal function. Estimated blood loss and post-transplant hospital stays were significantly lower in RKT group than in OKT group. LC analysis of RKT by the single surgeon revealed that surgical competence was achieved after 15 cases.

Conclusion: Even if surgeons do not have prior experience with MIS, they can rapidly overcome the LC and safely perform RKT with adequate preparation and acquisition of basic robotic surgical techniques.

Keywords: kidney transplantation, learning curve, regional hypothermia, robotic

Introduction

Kidney transplantation (KT) is the preferred treatment option for patients with end-stage kidney disease (ESKD). After the first report of successful KT in 1954[1], surgical techniques for KT predominantly relied on open surgery for many years. However, recent innovations in surgical techniques have led to universalization of minimally invasive surgery (MIS). Robotic surgery, in particular, has been remarkably successful across many surgical fields, with KT being no exception[2].

The first pure robotic kidney transplantation (RKT) was performed by Giulianotti *et al.*[3] at the University of Chicago. In 2013, Menon *et al.*[4] described the Vattikuti Urology Institute technique of RKT with regional hypothermia, which has since been adopted at various centers around the world[5–7]. The first pure RKT in South Korea was performed in November 2019 at our center[8]. Robotic surgery is known to have advantages in delicate tissue manipulation with a wide range of movements, ease of sutures including vascular anastomosis, and access to fields with difficult approaches. While experienced surgeons with

HIGHLIGHTS

- Kidney transplantation is the preferred treatment option for patients with end-stage kidney disease.
- Robotic kidney transplantation is a safe and effective minimally invasive alternative to open kidney transplantation, yielding comparable clinical outcomes.
- With adequate preparation, including essential training, even surgeons without prior minimally invasive surgery experience can rapidly and effectively overcome the learning curves.

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a background in robotic surgery are known to overcome the learning curve (LC) for RKT more easily, there is limited data on the feasibility and safety of performing RKT by surgeons lacking prior experience in MIS. In addition to the technical advantage of KT by robotic approach, it reduces the morbidity of open procedures, such as surgical site infection (SSI), wound dehiscence, and incisional hernia, particularly in obese patients, and accelerates patient recovery[9–12]. While numerous advantages of RKT have been reported, it is still challenging due to the relatively longer rewarming time compared to OKT, potentially affecting functional outcomes[13]. Furthermore, limited data are available regarding the feasibility and safety of performing RKT by surgeons lacking previous experience in MIS.

This study aimed to assess the surgical and functional outcomes of RKT for ESKD in comparison to OKT at a single institution. Additionally, we examined the LC for RKT performed by a single surgeon with no prior experience in any form of MIS.

Methods

Since the first KT began in 1979, as of April 2023, a total of 5210 cases (4388 living donors and 828 deceased donors) have been performed at Severance Hospital in Seoul, South Korea (Fig. 1). From November 2019, when RKT was first introduced, to April 2023, a total of 612 KTs (470 living donors and 142 deceased donors) were performed at our institution. Among these living donor kidney transplant (LDKT) cases, RKT was performed in 50 cases (50/470, 10.6%) by a single surgeon. To compare with RKT patients, open LDKT recipients were screened from those who underwent surgery by the same surgeon during the same period ($n=220$), excluding HLA-incompatible (HLAi) transplantation ($n=29$), retransplantation ($n=12$), and cases involving simultaneous surgeries ($n=20$). A total of 104 OKT patients who received surgery for the left kidney with a single artery and vein on the right side of patient under anatomically similar conditions to RKT were enrolled (Fig. 2).

At our institution, RKT is not considered for patients with previous major abdominal surgery because of their high likelihood of intra-abdominal adhesions. RKT is also not performed in patients with significant atherosclerotic disease of the iliac vessels, those undergoing second KT or simultaneous dual or multiple organ transplantation, and patients with an anticipated prolonged warm ischemia time (e.g. complex donor blood vessel anatomy).

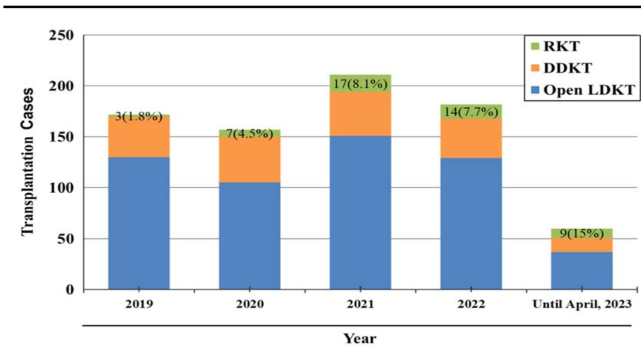

Figure 1. Annual trends in the proportion of kidney transplantation procedures performed at our institution.

All living donations were voluntary, and all donors were evaluated by transplant surgeons, urologists, nephrologists, and clinical psychologists, according to the KDIGO guidelines[14]. Also, donors for RKT with vascular anomalies, such as retro-aortic renal vein, duplicated Inferior Vena Cava, or multiple renal arteries, were not selected. All of the patients' data were collected through electronic medical record database and analyzed retrospectively. All study procedures were conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of our Hospital (4-2023-0373). Informed consent was waived by the Institutional Review Board due to the study's retrospective design. This study has been reported in line with the strengthening the reporting of cohort, cross-sectional and case–control studies in surgery (STROCSS) criteria[15] (Supplemental Digital Content 1, http://links.lww.com/JS9/B515).

Definitions of variables

Pre-emptive transplantation was defined as KT performed before initiation of chronic maintenance dialysis. Total operative time was recorded from the start of the skin incision to the end of skin closure. Docking time was defined as the time from the start of operation to the docking of a robotic system. Console time was the interval from docking of the robotic system to completion of console-reliant surgery. Undocking time was described as the time from the undocking of a robotic system to the completion of surgery. Cold ischemia time commenced at the start of on-table perfusion and ended when the graft was introduced into the recipient's abdomen. Rewarming time began thereafter and continued until full revascularization was achieved[16].

Delayed graft function (DGF) was defined as the need for dialysis within the first week after transplantation. Postoperative complications were categorized according to the Clavien–Dindo classification system[17]. SSI was defined as a positive wound culture or presence of wound exudate within the first 30 days after KT. Other recorded postoperative variables were serum creatinine at hospital discharge, and estimated glomerular filtration rate (eGFR).

Surgeon characteristics and preparation process for introduction of RKT

RKT has been performed by a single surgeon (Dr. Kyu Ha Huh) at our institution. He was the first surgeon to perform RKT in South Korea. Prior to his first RKT, he had performed more than 1000 open KTs but had no prior experience with MIS, including robotic or laparoscopic surgery.

He dedicated 1 year to prepare for the introduction of RKT. The surgeon completed basic training through the da Vinci Technical Training Pathway and an online training program. To acquire fundamental surgical skills with the robotic system, the surgeon used a simulator, initially practicing two to three times a month for 1 month, and then increased the frequency to once a week, dedicating 2 h each time, starting 6 months before the first case. Notably, in preparation for vascular anastomosis, the surgeon practiced end-to-end continuous anastomosis by cutting the finger portion of surgical gloves. Working alongside Dr Menon, who played a significant role in standardizing RKT, Dr Wooju Jeong, with extensive experience in various urological robotic surgeries and a wealth of supervision experience in robotic transplant surgery programs at other hospitals, shared advice and

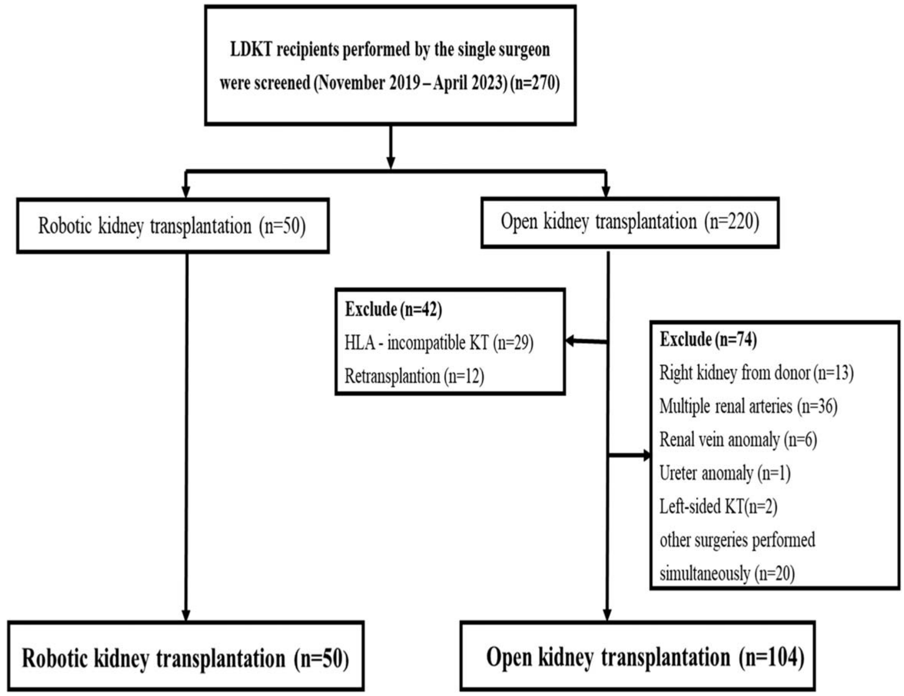

Figure 2. Study flow.

protocols for basic preparation and supervised introduction of RKT in our institution[4,18]. In March 2019, a cadaver workshop was conducted, and 1 week before the surgery, both the operator and assistant practiced and inspected basic robotic surgical techniques in the animal lab. The first two cases were conducted with the expert guidance (Dr Jeong) on the dual console. For this aspect, the patients were provided with an explanation and gave their informed consent before proceeding. Starting from the third case, the surgeon operated independently without any supervision.

Surgical procedure of RKT

We performed RKT with regional hypothermia using the transperitoneal approach, following the step-by-step manner outlined in the Vattikuti Urology Institute-Medanta technique utilizing the da Vinci Robotic Surgical System (da Vinci Si/Xi; Intuitive Surgical Inc)[18]. Once general anesthesia was induced (with the patient in the supine position), we incised the periumbilical skin (6–7 cm) to allow insertion of a GelPOINT device (Applied Medical Resources Corp, Rancho Santa Margarita) with camera access (12 mm) and assistance (10 mm) ports[19]. Three 8 mm robotic ports and one 12 mm assistant port were then positioned (Fig. 3 A, B). Unlike previously reported RKT procedures, the patient remained in a 15–20° Trendelenburg (not lithotomy) position during the operation, and the da Vinci Si unit was docked to the left of the patient's legs. These strategies appeared to facilitate the procedure and alleviate any discomfort caused by the lithotomy posture[8].

Briefly, external iliac vessels were first identified and completely dissected (Fig. 3 C). A peritoneal flap was then formed for retroperitonealization of the kidney, incising transversely on both sides of psoas muscle (Fig. 3 D). Next, the bladder was dissected and taken down. A 2 cm to 3 cm incision of bladder wall was made to create a detrusor flap, exposing bladder mucosa. To facilitate anastomosis under regional hypothermia, the entire kidney (excluding hilar structures) was wrapped in gauze with icy slush. The prepared graft was then introduced into the abdominal cavity by GelPOINT device, placing the kidney left of right external iliac vessels to rest naturally at bladder.

The grafted renal vein was anastomosed to the right external iliac vein in end-to-side continuous suture (Fig. 3 E). Subsequently, the grafted renal artery was anastomosed end-to-side as above (Fig. 3 F). Then the graft was reperfused. Positioning of the grafted kidney was ultimately reversed, situated lateral to right external iliac vessels. At this point, the kidney was retroperitonealized, to approximate the earlier raised peritoneal flaps.

Last, the ureter was anastomosed to bladder mucosa using continuous suture and Lich-Gregoir technique (Fig. 3 G). Subsequently, to exert antireflux effect, the detrusor muscle was closed over the ureter.

LC analysis

We evaluated LCs to describe the number of cases associated with this single surgeon achieving competency when learning the RKT technique[20]. We generated moving average charts for console time and rewarming time and performed cumulative summation (CUSUM) analysis to assess LCs for RKT using R package v. 4.0.3 (R Foundation for Statistical Computing)[21,22].

Statistical analysis

Results are expressed as mean and SD (range) or median and IQR number (percentage). Continuous variables were compared using Student's *t*-test for parametric data expressed as mean value or

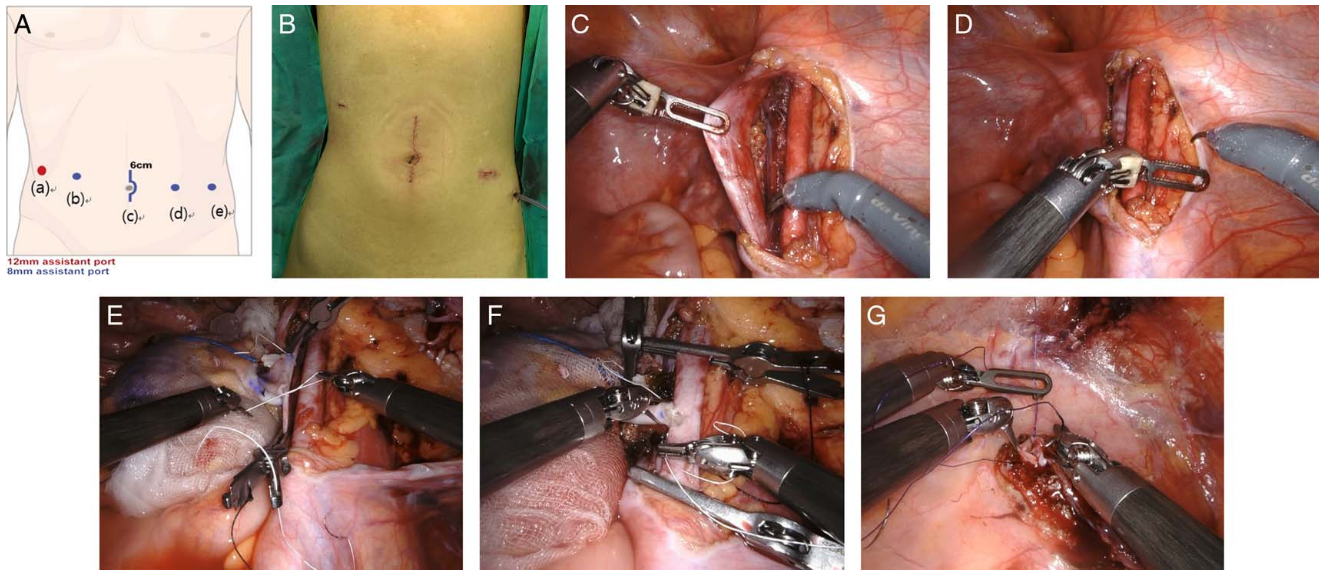

Figure 3. Surgical procedure of robotic kidney transplantation. (A) Trocar positioning (a) 12 mm assistant port, (b), (d), (e) 8 mm robotic ports, (c) periumbilical incision for inserting a GELPOINT device with camera access (12 mm) and assistant (10 mm) ports, (B) Postoperative wound, (C) The right external iliac vessel is fully dissected. (D) Peritoneal flap is created for retroperitonealization of the kidney. (E) The graft renal vein is anastomosed in an end-to-side continuous method to the external iliac vein. (F) The graft renal artery is anastomosed in an end-to-side continuous method to the external iliac artery. (G) The ureter is anastomosed to bladder mucosa using Lich-Gregoir technique.

Mann–Whitney test for nonparametric data expressed as median value. Changes of renal function over time were analyzed by repeated-measures ANOVA test. All tests were performed two-tailed, and *P*-values <0.05 were considered statistically significant. All statistical analyses were performed using SPSS for Windows v. 26.0 (IBM Corp.).

Results

Baseline characteristics

A total of 50 patients who underwent RKT and 104 patients who underwent OKT were included in this study. The baseline characteristics of patients are presented in Table 1. The mean recipient age at the time of RKT was 45.1 ± 11.2 years, and the male to female ratio was 35:15. Mean BMI was 22.0 ± 3.4 kg/m^2 (16–35). RKT was performed preemptively in 44% of patients. Eleven patients (22%) of RKT underwent ABO-incompatible (ABOi) KT, and all KTs were performed in the setting of HLA compatibility. Compared to OKT patients, RKT patients were significantly younger and more likely to have received a kidney from a female donor.

All grafts were retrieved laparoscopically from live donors who had no vascular or ureteral anomalies. All grafts were left-sided kidneys, consisting of one renal artery and one renal vein.

Operative and perioperative outcomes

Operative outcomes are summarized in Table 2. In RKT group, the median surgical console time was 193 min (IQR,

Table 1

Baseline characteristics of study population.

	RKT (*n* = 50)	OKT (*n* = 104)	
Preoperative parameters	**Mean ± SD (range); Frequency (%); Median (IQR)**		***P***
Recipient age, years	45.1 ± 11.2 (19–64)	51.8 ± 12.1 (19–79)	0.001
Recipient Sex, male-to-female ratio (%)	35 (70) : 15 (30)	62 (59.6) : 42 (40.4)	0.211
Recipient BMI, kg/m²	22.0 ± 3.4 (16.5–35.0)	23.9 ± 4.1 (16.5–36.9)	0.644
Dialysis duration, m	7.7 ± 25.2 (0–168)	8.4 ± 17.8 (0–105)	0.882
Pre-emptive, *n* (%)	22 (44.0)	38 (36.5)	0.659
HLA mismatch, *n*	3.2 ± 1.5 (0–6)	2.9 ± 1.7 (0–6)	0.231
ABO-incompatible KT, *n* (%)	11 (22.0)	35 (33.7)	0.139
Recipient –Donor relation, *n* (%)			0.897
Living-related	27 (54.0)	55 (52.9)	
Donor age, years	47.1 ± 11.1 (23–65)	48.1 ± 13.0 (19–70)	0.662
Donor Sex, male-to-female ratio (%)	12 (24.0) : 38 (76.0)	45 (43.3) : 59 (47.1)	0.020
Donor BMI, kg/m²	23.4 ± 2.7 (18.4–30.9)	24.2 ± 2.6 (18.2–30.0)	0.160

OKT, open kidney transplantation; RKT, robotic kidney transplantation.

Table 2

Operative data.

Operative parameters	RKT ($n=50$)	OKT ($n=104$)	P
	Mean ± SD (range); Frequency (%); Median (IQR)		
Total operation time, min	323 (290–371)	210 (190–239)	< 0.001
Console time, min	193 (172–222)		
Docking time, min	28 (23–32)		
Undocking time, min	60.0 (52.0–69.5)		
Cold ischemia time, min	34 (31–40)		
Rewarming time, min	62.5 (56.0–70.0)	25 (21–30)	< 0.001
Arterial anastomosis time, min	15 (13–19)		
Venous anastomosis time, min	21.0 (20.0–25.3)		
Ureteroneocystostomy time, min	33 (27–41)		
Estimated blood loss, ml	100 (50–150)	200 (100–300)	< 0.001
Intraoperative transfusion, n (%)	15 (30.0%)	41 (39.4%)	0.249
Incision length, cm	6–7	15–20	

OKT, open kidney transplantation; RKT, robotic kidney transplantation.

172–222) and the median vascular anastomoses time was 38 min (IQR, 35–44). The median total operation time was 323 min (IQR, 290–371) with a rewarming time of 62.5 min (IQR, 56.0–70.0) in RKT group compared to 210 min (IQR, 190–239) and 25 min (IQR, 21–30) in OKT group, respectively ($P<0.001$). Despite the extended surgical times with a robotic technique, both groups exhibited comparable surgical and functional outcomes. DGF did not occur in any patient in RKT group. Both groups showed comparable renal function on postoperative day 3, postoperative day 7, and discharge day (RKT, 1.2 ± 0.3 mg/dl (0.6–2.1) vs. OKT, 1.2 ± 0.5 mg/dl (0.6–5.4), $P=0.448$) (Supplemental Table 1, Supplemental Digital Content 2, http://links.lww.com/JS9/B516 and Fig. 1, Supplemental Digital Content 3, http://links.lww.com/JS9/B517). The median estimated blood loss (RKT, 100 ml vs. OKT, 200 ml, $P<0.001$) and post-transplant hospital stays (RKT, 8 days vs. OKT, 14 days, $P<0.001$) were significantly lower in RKT group than in OKT group. The incision length for RKT was ~6–7 cm, which exhibited a difference of approximately one-third to one-half compared to the 15–20 cm incision length for OKT (Fig. 3 B and Supplemental Fig. S2, Supplemental Digital Content 4, http://links.lww.com/JS9/B518).

Perioperative complications

In RKT group, no patient required conversion to open KT surgery. Clavien–Dindo complications of grade 3 or higher occurred in only one patient (Table 3). This patient developed a subcapsular hematoma and urinary leakage due to penetrating injury of the proximal ureter during ureteral stent insertion, which resolved with percutaneous drainage and ureteral stent reinsertion. One patient experienced paralytic ileus on postoperative day 2, which resolved within a day after nasogastric tube insertion. No patient in RKT group required anastomosis revision, or developed SSI or lymphocele (Table 4). Both groups showed comparable postoperative complications ($P=0.219$).

LC analysis

Figure 4 shows the tendency of console time to decrease over time (Fig. 4). CUSUM analysis revealed that the single surgeon could achieve competence in RKT after 15 cases (Fig. 5). Until the first 15 cases, there was an upward trend in average surgical console time, which was longer than the overall average duration. However, after the 15th case, a decrease in console time was observed, which was also confirmed by the moving average, indicating a similar trend. Similar results were obtained for rewarming time, which required 18 cases before a downward trend was observed (Fig. 6).

Discussion

This study presents promising outcomes of RKT from living donors conducted at a single institution. Using a modified Vattikuti Urology Institute-Medanta technique with regional hypothermia, we have successfully performed 50 cases of pure robotic-assisted KT since introducing RKT for the first time in South Korea. All operations had an acceptable overall duration and led to surgical and perioperative functional results comparable to those seen with conventional KT. There were almost no major complications, and no patient required conversion to open surgery. Our LC analysis suggested that RKT can be a safe and viable alternative to OKT, even when a surgeon has no prior experience with robotic or laparoscopic surgery.

Despite steady advancements in KT, surgical techniques remained stagnant for many years, with the classic retroperitoneal, open approach preferred because of concerns about the immunocompromised status of transplant recipients[23]. Nevertheless, it is not surprising that a minimally invasive approach for KT would eventually materialize, given the notable advantages of robotic surgery[24]. The first successful RKT was reported by Giulianotti *et al.*[3] , but it was Menon's group that spearheaded the standardization of RKT procedures[4,18]. Their study was the first to utilize regional hypothermia for reducing rewarming ischemic injury by wrapping kidneys in jackets filled with icy slush and sustained through GelPOINT supplementation.

Table 3

Perioperative and postoperative outcomes.

Peri-and post-operative outcomes	RKT ($n=50$)	OKT ($n=104$)	P
	Mean ± SD (range); Frequency (%); Median (IQR)		
Surgical complication			0.219
Conversion to open surgery	0 (0)		
Graft vascular complications	0 (0)	2 (1.9)	
Surgical site infection	0 (0)	0 (0)	
Intraperitoenal hematoma	1 (2.0)	0 (0)	
Subcapsular hematoma	1 (2.0)	2 (1.9)	
Urine leakage	1 (2.0)	0 (0)	
Delayed graft function	0 (0)	2 (1.9)	0.158
Serum Creatinine level on discharge, mg/dl	1.2 ± 0.3 (0.6–2.1)	1.2 ± 0.5 (0.6–5.4)	0.448
eGFR (CKD-EPI) on discharge, ml/min/1.73 m²	70.0 ± 17.6 (36–112)	73.0 ± 19.4 (11–123)	0.655
post-transplant hospital stays, days	8 (7–9)	14 (12–17)	< 0.001

eGFR, estimated glomerular filtration rates; OKT, open kidney transplantation; RKT, robotic kidney transplantation.

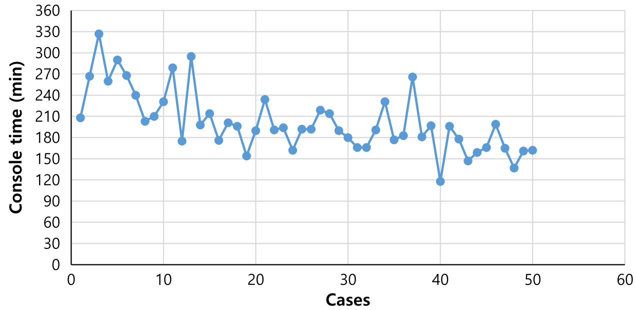

Figure 4. Trends for surgical console time.

They also established a set of standardized steps for purely RKT. Using a procedure modified slightly from the Vattikuti Urology Institute-Medanta technique, we performed the first KT in South Korea based entirely on robotics[8]. Our modifications included performing the surgery in the supine (not lithotomy) position and docking the da Vinci Si system to the left of (not between) the patient's legs. These strategies appeared to ease the operation and alleviate the postoperative discomfort caused by the lithotomy position.

Recently published systematic reviews with meta-analysis emphasized the beneficial effects of minimally invasive techniques for KT[13,25]. RKT was associated with lower rates of wound complications and lymphocele, as well as less blood loss, compared with conventional OKT. Regarding functional outcomes, renal function and graft and patient survival were similar after RKT versus OKT. Our outcomes are consistent with the results reported in other RKT series. Although this could be attributed to the shorter ischemic time in LDKT, no cases of DGF were observed in RKT group[26]. We encountered no wound complications, lymphocele, or vascular complications. While RKT is often considered advantageous for patients with higher BMI in terms of wound complications, our population generally had lower BMI[12]. However, it is worth noting that Asians tend to have lower BMIs compared to Western populations. In our data, even the open surgery group had relatively low BMI, and there was no statistically significant difference in BMI between the two groups (RKT, 22.0 ± 3.4 (16.5–35.0) vs. OKT, 23.9 ± 4.1 (16.5–36.9) kg/m², $P = 0.644$). From the patient's perspective, RKT is associated with a shorter post-transplant hospital stays (median 8 days on RKT vs. 14 days on OKT, $P < 0.001$), better cosmetic results (incision size, 6–7 cm on RKT vs. 15–20 cm on OKT), less perioperative morbidity, and less postoperative pain than open KT, thereby increasing patient satisfaction.

RKT is not without limitations or controversy. There have been concerns about the relatively longer rewarming time required for RKT during vascular anastomoses, which may affect graft function[27–29]. However, this study demonstrated that despite the longer surgical duration associated with the robotic technique, postoperative renal function in both RKT and OKT groups is comparable. Also use of regional hypothermia, as suggested by Menon *et al.*[18], reduces graft impairment during the rewarming period. During vascular anastomosis, use of cold saline irrigation or, if necessary, ice slush is performed to maintain cooling within the intraperitoneal vicinity of the graft, and the gap in rewarming time between RKT and OKT is narrowed by reducing the rewarming time to ~50 min after overcoming the LC. There have also been concerns that intraperitoneal ice cooling induces postoperative ileus[5]. Although we noted paralytic ileus in one patient on postoperative day 2, which resolved a day after inserting a nasogastric tube, it is unclear whether intraperitoneal ice cooling contributed to the ileus. The potential effects of

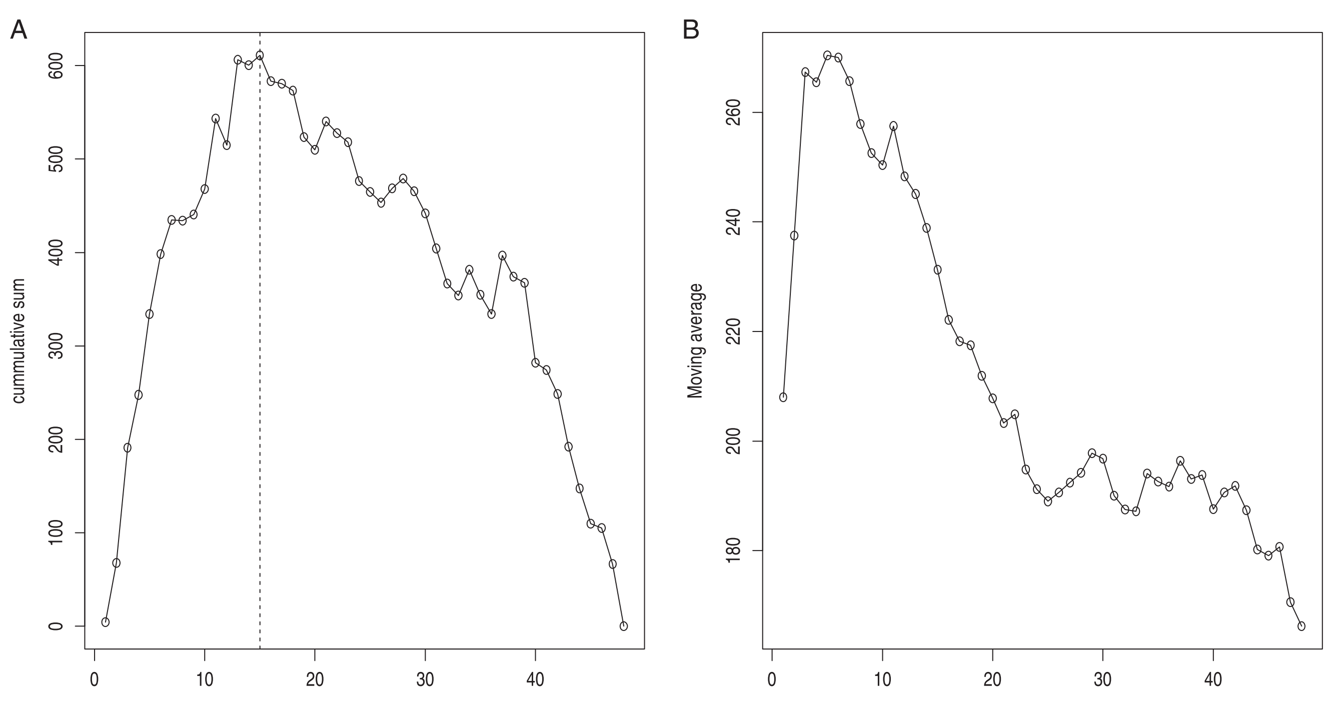

Figure 5. Learning curve analysis for surgical console time. (A) Cumulative summation (CUSUM) analysis and (B) moving average chart.

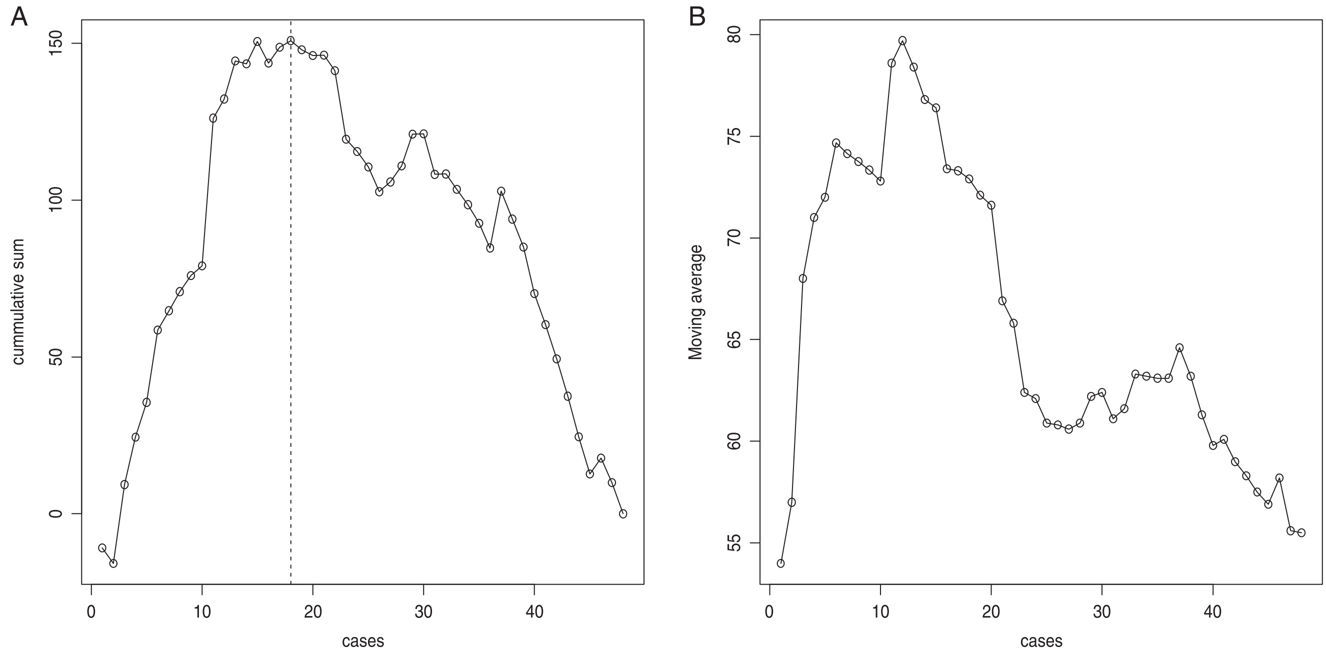

Figure 6. Learning curve analysis for rewarming time. (A) Cumulative summation (CUSUM) analysis and (B) moving average chart.

rewarming time on outcomes and of ice cooling on complications require further evaluation in studies with longer follow-up and a larger number of patients.

In a recently published systematic review, the majority of studies on RKT were performed by surgeons with expertise in both robotic surgery and OKT[13,16,25]. Sood *et al.*[30] reported that LCs were notably longer for surgeons without prior robotic surgery experience than for those with prior robotic experience. The surgeon in our study had significant experience performing OKT but no prior experience with MIS, including robotic surgery. The LC for RKT of this surgeon was 15 cases (for console time), which was similar to the number previously reported for surgeons skilled in robotic surgery[16,31]. Robotic surgery offers clear advantages that contribute to a relatively short LC, even for surgeons without previous MIS experience[2,9,32]. The robotic device provides stable camera guidance with a three-dimensional view and magnification and allows a broad range of movements, all of which make it possible to perform precise vascular anastomoses and delicate tissue manipulation, with better accessibility in otherwise challenging situations. Nevertheless, it is crucial for surgeons lacking experience with MIS to carefully select suitable patients for the procedure and to establish a collaborative partnership with experienced team members to expedite their progression through the learning phase of RKT[5]. Our institution has been at the forefront of robotic surgery in our country since 2005, achieving a significant milestone of 40 000 robotic surgeries by September 2023. Therefore, our center has proven expertise in the field of robotic surgery, with several prominent surgeons providing valuable consultations[33–35]. Also, our institution has South Korea's first advanced robotic training center, certified by Intuitive Surgical, Inc This center ensures a well-structured training system and nurtures a team of highly trained professionals with extensive experience in robotic surgery. Therefore, it is thought that our institution's pioneering experience with robotic surgery has contributed to lowering the barrier to entry for our single surgeon, who has no experience in robotic surgery, to introduce the first RKT in South Korea.

Some important factors to consider when selecting candidates for RKT are whether the surgery can be performed safely and feasibly with minimal invasiveness and without an unusually long warm ischemia time[18]. Initially, we adopted highly selective patients for RKT indications, avoiding challenging cases with characteristics such as a prior abdominal surgery, less favorable recipient and donor vascular conditions, risk of bleeding due to preoperative desensitization procedures, such as ABOi KT, or high immunological risk, such as HLAi KT. With more experience, we have gradually expanded our indications of RKT. With our 11th RKT, we have also initiated our first attempt at ABOi KT. Now that we have overcome the learning phase at our institution, as our experience accumulates, we intend to broaden the indications for RKT over time to include other situations, such as donors with multiple renal arteries, recipients with morbid obesity despite our initial absence on BMI restrictions, HLAi KT, and deceased-donor KT[36–38]. This study is important as it shows that even surgeons lacking experience in robotic surgery can safely venture into RKT for carefully selected patients with adequate preparation.

This study has limitations worth considering. First, it is a single-center retrospective study, with the usual drawbacks of a retrospective study, as well as potentially limited generalizability. Careful selection of indications for RKT may have led to selection bias. However, the single-center, single-surgeon study design has the advantages of homogeneous operation procedures and follow-up protocols. Second, as with any observational study and considering the multifactorial nature of LCs, we cannot exclude the possibility of potential confounders affecting our LC results. This study also presents LCs for only surgical outcomes, and follow-up studies should be conducted to evaluate LCs for short-term and

Table 4

Complication graded according to Clavien–Dindo classification.

Clavien–dindo classification	RKT ($n=50$)	OKT ($n=104$)	
	Mean ± SD (range); Frequency (%); Median (IQR)		*P*
Grade I	0 (0)	1 (1.0)	
Grade II	1 (2.0)	5 (4.8)	
Grade III			
IIIa	0 (0)	2 (1.9)	
IIIb	1 (2)	1 (1.0)	
Grade IV	0 (0)	0 (0)	
Grade V	0 (0)	0 (0)	
Total	2 (4.0)	9 (8.7)	0.175

OKT, open kidney transplantation; RKT, robotic kidney transplantation.

long-term functional outcomes. Further research is also necessary to investigate whether comparable outcomes can be achieved with RKT versus OKT.

Conclusion

Even if surgeons do not have prior experience with MIS, they can rapidly overcome the LC and safely perform RKT with adequate preparation and acquisition of basic robotic surgical techniques.

Ethical approval

All study procedures were conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Severance Hospital (4-2023-0373).

Consent

Patient consent for this study was waived because of its retrospective design.

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Author contribution

H.J.K.: data acquisition, statistical analysis, writing, and revision of the manuscript; K.H.H.: study design, data acquisition, statistical analysis, writing, and revision of the manuscript; W.J., S.J.Y., J.L., J.S.L., J.C.N., and W.K.H.: data acquisition, interpreted the data.

Conflicts of interest disclosure

We have no conflicts of interest.

Research registration unique identifying number (UIN)

1. Name of the registry: researchregistry.
2. Unique identifying number or registration ID: researchregistry9403.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-the-registry#home/.

Guarantor

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Data availability statement

Datasets generated during the current study are available, upon reasonable request.

Provenance and peer review

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References

[1] Merrill JP, Murray JE, Harrison JH, *et al*. Successful homotransplantation of the human kidney between identical twins. J Am Med Assoc 1956; 160:277–82.
[2] Lanfranco AR, Castellanos AE, Desai JP, *et al*. Robotic surgery: a current perspective. Ann Surg 2004;239:14.
[3] Giulianotti P, Gorodner V, Sbrana F, *et al*. Robotic transabdominal kidney transplantation in a morbidly obese patient. Am J Transplant 2010;10:1478–82.
[4] Menon M, Sood A, Bhandari M, *et al*. Robotic kidney transplantation with regional hypothermia: a step-by-step description of the Vattikuti Urology Institute-Medanta technique (IDEAL phase 2a). Eur Urol 2014; 65:991–1000.
[5] Breda A, Territo A, Gausa L, *et al*. Robot-assisted kidney transplantation: the European experience. Eur Urol 2018;73:273–81.
[6] Vignolini G, Greco I, Sessa F, *et al*. The University of Florence technique for robot-assisted kidney transplantation: 3-year experience. Front Surg 2020;7:583798.
[7] Territo A, Gausa L, Alcaraz A, *et al*. European experience of robot-assisted kidney transplantation: minimum of 1-year follow-up. BJU Int 2018;122:255–62.
[8] Kim HJ, Yang SJ, Jeong W, *et al*. The first robotic kidney transplantation in Korea: a case report, Korean. J Transplant 2022;36:61–6.
[9] Pein U, Girndt M, Markau S, *et al*. Minimally invasive robotic versus conventional open living donor kidney transplantation. World J Urol 2020;38:795–802.
[10] Ahlawat R, Sood A, Jeong W, *et al*. Robotic kidney transplantation with regional hypothermia versus open kidney transplantation for patients with end stage renal disease: an ideal stage 2B study. J Urol 2021;205: 595–602.
[11] Hameed AM, Yao J, Allen RDM, *et al*. The evolution of kidney transplantation surgery into the robotic era and its prospects for obese recipients. Transplantation 2018;102:1650–65.
[12] Tzvetanov IG, Spaggiari M, Tulla KA, *et al*. Robotic kidney transplantation in the obese patient: 10-year experience from a single center. Am J Transplant 2020;20:430–40.

[13] Slagter JS, Outmani L, Tran KT, *et al*. Robot-assisted kidney transplantation as a minimally invasive approach for kidney transplant recipients: a systematic review and meta-analyses. Int J Surg 2022;99:106264.
[14] Chadban SJ, Ahn C, Axelrod DA, *et al*. KDIGO clinical practice guideline on the evaluation and management of candidates for kidney transplantation. Transplantation 2020;104(4S1):S11–103.
[15] Mathew G, Agha R, Albrecht J, *et al*. STROCSS 2021: strengthening the reporting of cohort, cross-sectional and case-control studies in surgery. Int J Surg Open 2021;37:100430.
[16] Ahlawat RK, Tugcu V, Arora S, *et al*. Learning curves and timing of surgical trials: robotic kidney transplantation with regional hypothermia. J Endourol 2018;32:1160–5.
[17] Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205.
[18] Menon M, Abaza R, Sood A, *et al*. Robotic kidney transplantation with regional hypothermia: evolution of a novel procedure utilizing the IDEAL guidelines (IDEAL phase 0 and 1). Eur Urol 2014;65:1001–9.
[19] Menon M, Tewari A, Peabody J. V.I.P. Team. Vattikuti Institute prostatectomy: technique. J Urol 2003;169:2289–92.
[20] Pennell C, Hirst A, Campbell W, *et al*. Practical guide to the idea, development and exploration stages of the IDEAL framework and recommendations. J Br Surg 2016;103:607–15.
[21] Wohl H. The cusum plot: its utility in the analysis of clinical data. N Engl J Med 1977;296:1044–5.
[22] Williams SM, Parry BR, Schlup M. Quality control: an application of the cusum. Br Med J 1992;304:1359.
[23] Burgos FJ, Pascual J, Quicios C, *et al*. Post-kidney transplant surgical complications under new immunosuppressive regimens. Transplant Proc 2006;38:2445–7.
[24] Bruyere F, Doumerc N. Robotic kidney transplantation: dream or future? Curr Opin Urol 2018;28:139–42.
[25] Wagenaar S, Nederhoed JH, Hoksbergen AW, *et al*. Minimally invasive, laparoscopic, and robotic-assisted techniques versus open techniques for kidney transplant recipients: a systematic review. Eur Urol 2017;72:205–17.
[26] Perico N, Cattaneo D, Sayegh MH, *et al*. Delayed graft function in kidney transplantation. Lancet 2004;364:1814–27.
[27] Territo A, Mottrie A, Abaza R, *et al*. Robotic kidney transplantation: current status and future perspectives. Italian J Urol Nephrol 2016;69: 5–13.
[28] Kayler L, Magliocca J, Zendejas I, *et al*. Impact of cold ischemia time on graft survival among ECD transplant recipients: a paired kidney analysis. Am J Transplant 2011;11:2647–56.
[29] Weissenbacher A, Oberhuber R, Cardini B, *et al*. The faster the better: anastomosis time influences patient survival after deceased donor kidney transplantation. Transpl Int 2015;28:535–43.
[30] Sood A, Ghani KR, Ahlawat R, *et al*. Application of the statistical process control method for prospective patient safety monitoring during the learning phase: robotic kidney transplantation with regional hypothermia (IDEAL phase 2a–b). Eur Urol 2014;66:371–8.
[31] Gallioli A, Territo A, Boissier R, *et al*. Learning curve in robot-assisted kidney transplantation: results from the European Robotic Urological Society Working Group. Eur Urol 2020;78:239–47.
[32] Diana M, Marescaux J. Robotic surgery. J Br Surg 2015;102:e15–28.
[33] Lee W-J. Ten-year experience of the da Vinci robotic surgery at Severance Yonsei University Hospital in Korea. Hanyang Med Rev 2016;36: 215–24.
[34] Ryu JM, Kim JY, Choi HJ, *et al*. Robot-assisted nipple-sparing mastectomy with immediate breast reconstruction: an initial experience of the Korea Robot-Endoscopy Minimal Access Breast Surgery Study Group (KoREa-BSG). Ann Surg 2022;275:985–91.
[35] Koh DH, Jang WS, Park JW, *et al*. Efficacy and safety of robotic procedures performed using the da Vinci robotic surgical system at a single institute in Korea: experience with 10000 cases. Yonsei Med J 2018;59:975–81.
[36] Nataraj SA, Zafar FA, Ghosh P, *et al*. Feasibility and functional outcome of robotic assisted kidney transplantation using grafts with multiple vessels: comparison to propensity matched contemporary open kidney transplants cohort. Front Surg 2020;7:51.
[37] Spaggiari M, Petrochenkov E, Gruessner A, *et al*. Robotic kidney transplantation from deceased donors: a single-center experience. Am J Transplant 2023;23:642–8.
[38] Oberholzer J, Giulianotti P, Danielson K, *et al*. Minimally invasive robotic kidney transplantation for obese patients previously denied access to transplantation. Am J Transplant 2013;13:721–8.