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ORIGINAL ARTICLE

Robotic-assisted vs. laparoscopic donor nephrectomy: a retrospective comparison of perioperative course and postoperative outcome after 1 year

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Abstract Safety is of utmost importance in live donor nephrectomies. In this study, we describe our initial experience with robot-assisted laparoscopic donor nephrectomy (RDN) in comparison with the standard laparoscopic donor nephrectomy (LDN). We retrospectively reviewed 95 patients who either underwent RDN or LDN performed by a single surgeon from 2011 to 2016 at a tertiary institution. Donor perioperative course and postoperative outcome along with recipient outcomes were compared. Of the 95 cases, 73 were classified as LDN and 22 were classified as RDN. There were no significant differences between the two groups in age, sex, BMI, race, and ASA status. Operative times ($p < 0.001$) were longer in the RDN group, but eventually approached LDN times. Warm ischemia ($p = 0.002$) and extraction times ($p = 0.05$) were also longer in the RDN cohort. The donor length of hospital stay, complication rates, and postoperative change in eGFR from baseline were similar in both cohorts up to 1 year. Recipient outcomes, including delayed graft function, graft failure, and renal function up to 1 year, were also comparable. In this study, we compared the longest postoperative course so far in both donors and recipients between RDN and LDN. Up to 1 year, RDN does not negatively impact outcomes. Proficiency with RDN also quickly improved to match LDN, making it a suitable procedure for newer surgeons.

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Abbreviations

ASA	American society of anesthesiologists
BMI	Body mass index
eGFR	Estimated glomerular filtration rate
IRB	Institutional review board
LDN	Laparoscopic donor nephrectomy
MDRD	Modification of diet in renal disease
RDN	Robot-assisted laparoscopic donor nephrectomy
WIT	Warm ischemia time

Introduction

Live donor nephrectomy is an elective procedure, where the patient undergoes surgery for the sole benefit of another individual. It is a procedure with minimal margin for error and the preferred outcome would be no change to the donor's preoperative condition. Even in the best case scenario, the patient may still experience pain, the cosmetic effects of the procedure, and loss of time from work. As such, the safety of the patient is of utmost importance, and every endeavor should be made to minimize risks and improve the donation experience.

Ratner et al. [1] first introduced laparoscopic donor nephrectomy (LDN) in 1995. LDN demonstrated several improvements over open donor nephrectomy, including decreased postoperative pain, decreased length of hospital stay, faster recuperation, and reduced perioperative blood loss [2]. Due to these advantages, LDN is currently the standard of care, and several modifications have been made to improve the technique. These modifications include hand-assisted LDN, laparoendoscopic single-site surgery, transvaginal LDN, and robot-assisted laparoscopic donor nephrectomy (RDN) [3–6]. The introduction of LDN as a minimally invasive procedure with decreased recovery time and better cosmetic results also brought about an initial increase in the number of available live kidney donors [7]. However, this trend has now reversed as there has been a recent decrease in living kidney donations from 6647 in 2004 to 5633 in 2016 [8]. With the advent of robotic surgery, RDN may be the next evolution of the surgical technique for donor nephrectomy as well as a potential solution to the decreasing donor pool.

The DaVinci Surgical System (Intuitive Surgical, Mountain View, CA, USA) was first introduced in 2000. Since then, multiple procedures have incorporated the assistance of the system [9–13]. Robotic surgery is now considered to be the preferred approach or even the standard of care in multiple procedures including partial nephrectomy and radical prostatectomy [14–17]. The surgical robot has been viewed as “enabling technology” as it enables surgeons to perform complex minimally invasive procedures, which may be facilitated by the greater degrees of freedom allowed [18]. Despite surgeons generally having less experience with robotic surgery, it has been shown that robotic cases have achieved equivalent outcomes compared to the conventional cases for perioperative variables, including blood loss and transfusion rate [19]. By decreasing the learning curve for difficult surgical tasks, surgical robots may also expand the number of available surgeons for complex procedures as well as allow newer surgeons to quickly master these procedures.

Robot-assisted laparoscopic donor nephrectomy (RDN) was first reported by Horgan [6]. They showed that RDN retained the cosmetic advantages of the standard LDN, but also allowed for seven degrees of freedom and 3D vision in comparison with the four degrees of freedom and 2D vision of LDN [6]. With these benefits, RDN can serve as a potential alternative to LDN. However, the efficacy and safety of the procedure, including long-term postoperative outcomes, have yet to be thoroughly examined. In this study, we describe our institution’s initial experience with RDN by retrospectively comparing intraoperative and postoperative outcomes of donors undergoing RDN and LDN, performed by a single surgeon.

Materials and methods

The study commenced after approval from the Icahn School of Medicine at Mount Sinai Institutional Review Board (IRB). Informed consent was waived by the IRB. Data, including operative and postoperative parameters, were collected from 73 standard laparoscopic donor nephrectomies and 22 robot-assisted laparoscopic donor nephrectomies performed by a single surgeon from 2011 to 2016. Live donor demographic data included age, sex, race, body mass index (BMI), ASA status, and kidney laterality. Operative parameters included estimated blood loss, operative time, warm ischemia time (WIT), and extraction time. Warm ischemia time was defined as the time from clamping of the renal artery to cold perfusion. Postoperative parameters for live donors included creatinine levels, hemoglobin levels, and complications at different timepoints. Outcomes of interest were renal function, postoperative complications at various timepoints including 2 weeks and 1 year. Complications were graded using the Clavien–Dindo system. Renal function was assessed by estimated glomerular filtration rate (eGFR), which was calculated from serum creatinine using the modification of diet in renal disease (MDRD) equation. Data on recipients of the 95 donor nephrectomies were also obtained. Recipient eGFR and creatinine at 1 month, 6 months, and 1 year after transplantation were collected along with incidents of delayed graft function and graft failure.

The surgical techniques for RDN and LDN were similar to procedures described in the previous literature [20, 21]. LDN was performed with 3 or 4 ports, depending on the laterality of the kidney, with possible hand assist. In the left LDN, a 5 mm port was placed near the umbilicus with two 12 mm ports at the mid-clavicular line in the lower quadrant and left of the midline in the upper quadrant. For the right LDN, the configuration is similar, but reflected about the midline with an additional 5 mm port at the superior midline for retraction of the liver. RDN was performed with 4 or 5 ports. In the left RDN, a 12 mm port was placed lateral to the umbilicus. Additional 8 mm ports were placed at three locations left of the midline in the upper quadrant, at the mid-clavicular line in the lower quadrant, and at the most lateral portion of the retroperitoneum above the iliac crest. An assistant 12 mm port was placed at the midline, below the umbilicus. The configuration is reflected for the right RDN with the additional of the 5 mm port for liver retraction. In all cases, the kidney was delivered through either a Pfannenstiel incision or a modified Gibson incision.

Patient characteristics and perioperative outcomes were compared between the two groups. Categorical variables were compared using the Chi-squared test. Continuous variables were compared using the Mann–Whitney U test. Statistical significance was set at a p value of 0.05 or less. Statistical analysis was performed using SPSS version 23 (IBM© Corp., Armonk, NY, USA).

Results

Between 2011 and 2016, a total of 95 individuals who underwent either laparoscopic donor nephrectomy or robot-assisted laparoscopic donor nephrectomy performed by a single surgeon were reviewed. Of the 95 patients, 73 patients underwent LDN, while the other 22 patients underwent RDN. Patient demographics are summarized in Table 1. No significant differences in age, sex, BMI, kidney laterality, race, and ASA status were found between the groups. Similarly, there were no significant differences in preoperative serum creatinine, hemoglobin, and eGFR.

Intraoperative data are shown in Table 2. RDN was associated with longer operating times (192.3 vs. 149.8 min, $p < 0.001$). Over the course of the robotic cases, the operating time of RDN eventually approached the mean operating time of LDN with each subsequent procedure. Figure 1 shows the learning curve of RDN operative time vs. surgery date fitted to a cubic regression with the mean operative time of LDN cases as reference. Warm ischemia times (3.4 vs. 2.2 min, $p = 0.002$) and extraction times (2.6 vs. 1.7 min, $p = 0.05$) were also found to be longer in the RDN group. There were no significant differences in estimated blood loss or need for blood transfusion. Hospital stay length was similar in both groups (2.5 vs. 2.8 days, $p = 0.365$).

Postoperatively, decrease in hemoglobin (12.8 vs. 8.3%, $p < 0.001$) was significantly greater in the RDN group (Table 3). Changes in serum creatinine (26.7 vs. 19.9%, $p = 0.086$) and eGFR (−22.3 vs. −16.9%, $p = 0.086$) were found to not significantly differ between the two groups. Postoperatively at 2 weeks, these changes in serum creatinine (47.7 vs. 51.1%, $p = 0.481$) and eGFR (−35.1 vs. −37.2%, $p = 0.481$) from baseline did not significantly differ. Similarly, at 1 year follow-ups, changes in serum creatinine and eGFR were not significantly different.

Table 4 summarizes the postoperative donor complications reported at three different timepoints postoperatively, 2 weeks postoperatively, and 1 year postoperatively. Postoperatively, 4 (5.5%) patients in the LDN group and 2 (9.1%) patients in the RDN group developed complications. Most of the complications were minor complications (Grade I–II), which consisted of fever, nausea, atelectasis, and chylous leakage. The only major complication (Grade IV) in the LDN group was acute pulmonary edema. At 2 week follow-up, there were 11 (15.1%) minor complications in the LDN group and 1 (4.5%) minor complication in the RDN group. Complications in the LDN group included nausea, abdominal/flank pain, epididymitis, seroma, arm paresthesia, wound infection, and diffuse rash. The single minor complication in the RDN group was the development of chylous ascites. At 1 year follow-up, there were 3 (4.1%) minor complications in the LDN group and 1 (4.5%) minor complications in the RDN group. These complications consisted of nausea and testicular soreness/swelling. There were no major complications at 1 year.

There was no difference in transplant patient and graft outcome regardless of the donor procedure performed. Transplant recipient renal function did not differ at 1 month, 6 months, or 1 year after transplantation (Table 5). In recipients who received kidneys from donors undergoing LDN, there were three cases of graft failure and one case of delayed graft function. For the three cases, graft failure did not occur immediately, but rather a few years after the transplantation in each case. There were no cases of graft failure or delayed graft function in recipients of donors undergoing RDN.

Table 1 Demographic and clinical characteristics of donors

	LDN ($N = 73$)	RDN ($N = 22$)	p
Age (years)	39.4 (11.3)	38.2 (11.4)	0.701
BMI (kg/m^2)	27.5 (4)	25.8 (4.4)	0.161
Male (%)	44 (60.3)	12 (54.5)	0.632
Left kidney (%)	58 (79.5)	20 (90.9)	0.219
Race (%)			0.163
White	34 (46.6)	8 (36.4)	
Black	13 (17.8)	3 (13.6)	
Hispanic	3 (4.1)	4 (18.2)	
Other	23 (31.5)	7 (31.8)	
ASA status (%)			0.13
1	56 (76.7)	20 (90.9)	
2	16 (21.9)	1 (4.5)	
Unknown	1 (4.5)	1 (4.5)	
Preoperative serum creatinine (mg/dL)	0.9 (0.2)	0.9 (0.2)	0.26
Preoperative hemoglobin (g/dL)	14 (1.4)	14.2 (1.3)	0.56
Preoperative eGFR (mL/min/1.73 m^2)	89.6 (15.3)	93.2 (16.1)	0.237

Table 2 Donor intraoperative outcomes

	LDN ($N = 73$)	RDN ($N = 22$)	p
EBL (mL)	45.8 (64.4)	55.9 (87.8)	0.897
Transfusion (%)	2 (1.4)	0 (0)	0.581
Operative time (min)	149.8 (33.7)	192.3 (26.2)	<0.001
Extraction time (min)	1.7 (0.5)	2.6 (0.1)	0.05
Warm ischemia time (min)	2.2 (1.2)	3.4 (1.1)	0.002
Length of hospital stay (days)	2.8 (1.3)	2.5 (0.6)	0.365

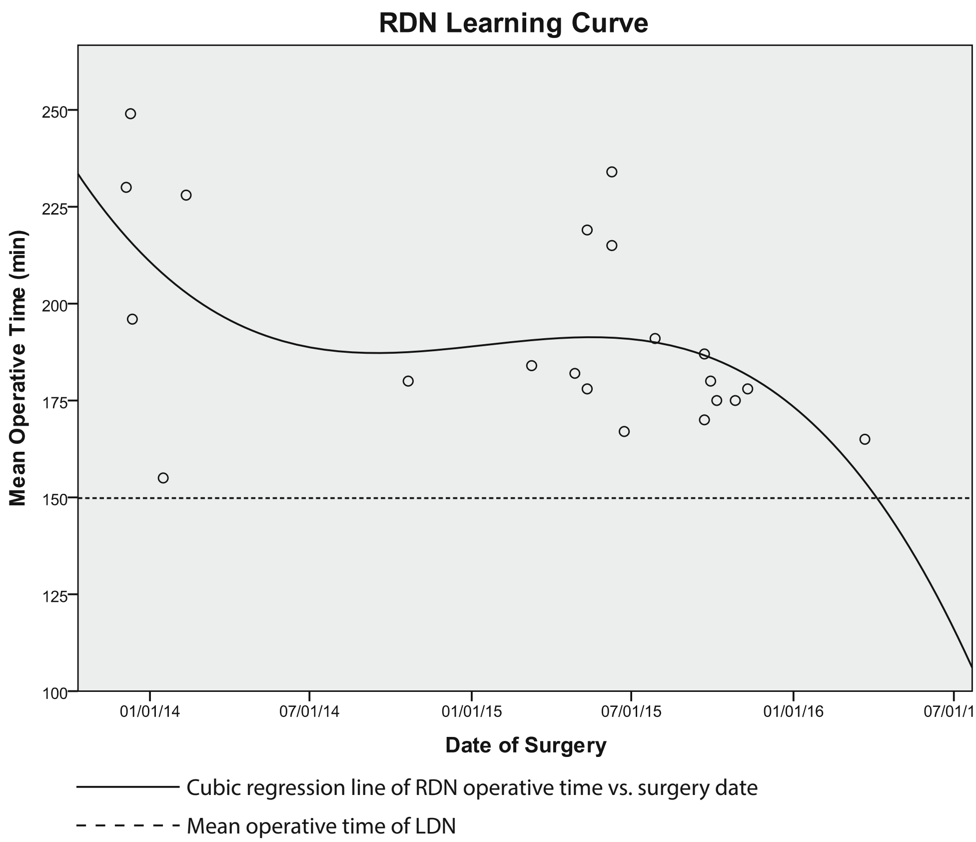

Fig. 1 Learning curve of RDN with operative time vs. date of surgery. The learning curve was fitted to a cubic regression ($R^2 = 0.286$). The *dashed line* is mean operative time of LDN for reference

Discussion

Live donor nephrectomy is a unique operation performed on healthy donors. As such, it is imperative to maintain the safety of the patient. Although LDN is currently accepted as the gold standard for various reasons, safety, along with its benefits and risks, had to be carefully assessed during its introduction before being widely adopted over open donor nephrectomy. Its reported benefits of shorter hospital stay, less pain, improved cosmesis, and faster return to work were balanced by longer operative times, longer WIT, steeper learning curve, and possible overlooked complications due to limited vision and control [22, 23]. In the same manner, the potential benefits and risks of RDN must also be assessed with regards to safety before it can be considered a viable alternative to LDN.

No differences were found in patient characteristics between RDN and LDN. With regard to perioperative outcomes, we found no differences in blood loss, transfusions, and length of hospital stay when compared to LDN. In this early experience, operative time, warm ischemia time, and extraction time were found to be longer in RDN as well as having greater hemoglobin change. The difference in hemoglobin change was not clinically relevant (−1.2 vs. −1.8 g/dL). The longer times could be a result of our cautious, slower approach with RDN, which was due to our initial unfamiliarity with the procedure. Longer warm ischemia times and extraction times could also be attributed to the extraction being performed by a second attending surgeon, because the primary attending surgeon was at the console, operating the robot. As more robotic cases were accomplished, the surgical technique was

Table 3 Donor postoperative outcomes

Timepoint	Variable	LDN ($N = 73$)	RDN ($N = 22$)	p
Postoperative	Postoperative hemoglobin (g/dL)	12.8 (1.5)	12.4 (1.5)	0.31
	Hemoglobin change (g/dL)	−1.2 (0.8)	−1.8 (0.5)	<0.001
	Hemoglobin change (%)	−8.3 (5.8)	−12.8 (3.9)	<0.001
	Postoperative creatinine (mg/dL)	1.1 (0.2)	1.1 (0.2)	0.87
	Postoperative creatinine change (mg/dL)	0.2 (0.2)	0.2 (0.1)	0.133
	Creatinine change (%)	19.9 (17.6)	26.7 (16.8)	0.086
	Postoperative eGFR (mL/min/1.73 m^2)	73.8 (14)	71.3 (10.7)	0.618
	Postoperative eGFR change (ml/min/1.73 m^2)	−15.8 (12.5)	−21.9 (13.7)	0.103
	eGFR change (%)	−16.9 (13)	−22.3 (11.9)	0.086
Postoperative at 2 weeks	Postoperative creatinine (mg/dL)	1.4 (0.3)	1.3 (0.2)	0.191
	Creatinine change (mg/dL)	0.5 (0.2)	0.4 (0.2)	0.193
	Creatinine change (%)	51.1 (15.3)	47.7 (16.9)	0.481
	Postoperative eGFR (mL/min/1.73 m^2)	56.1 (10.2)	59.8 (9.9)	0.127
	eGFR change (mL/min/1.73 m^2)	−33.6 (9.4)	−33.6 (11.4)	0.596
	eGFR change (%)	−37.2 (7.1)	−35.1 (10.1)	0.481
Postoperative at 1 year	Postoperative creatinine (mg/dL)	1.3 (0.3)	1.2 (0.2)	0.355
	Creatinine change (mg/dL)	0.4 (0.2)	0.4 (0.1)	1
	Creatinine change (%)	42.6 (16.5)	45.7 (18.9)	0.507
	Postoperative eGFR (mL/min/1.73 m^2)	60.7 (12.4)	60.6 (9.3)	0.988
	eGFR change (mL/min/1.73 m^2)	−29.4 (9.7)	−32.6 (12.5)	0.17
	eGFR change (%)	−32.5 (9.1)	−33.8 (11.3)	0.507

further refined and these times improved. In one instance, we found that extensive fat dissection around the kidney allowed for easier and faster retrieval of the kidney. Bhattu et al. also reported longer warm ischemia time and extraction time associated with RDN but similar operating time in both groups (Bhattu 2015). In their case, they explained the longer times as a result of unlocking the fourth arm during extraction of the kidney [24].

As RDN is a relatively new procedure, the learning curve is a possible cause of differences in a number of intraoperative factors including operative time and warm ischemia time. In our case, the surgeon performing the procedures had extensive experience with both laparoscopic and robotic procedures, but not necessarily the specific application of robotic surgery to donor nephrectomy. Because of the surgeon's extensive experience, we were able to minimize confounders related to operating the DaVinci robot and focus on execution of the procedure with robotic assistance. In our case, operative times were longer with the first few cases, but began to approach the mean LDN operative times by the last case (Fig. 1). Longer WIT could also be due to the learning curve as it has been previously shown that portions of RDN performed under warm ischemia take longer to master than less critical portions of the procedure [25]. We also realize that due to the surgeon's extensive experience that this learning curve may not be indicative of a surgeon with no prior robotic experience. For newer surgeons without robotic experience, they may face a steeper learning curve due to the challenges of learning both the robotic system and the procedure. Conversely, a surgeon with robotic experience can have a significantly easier time in learning to perform RDN compared to LDN.

From our experience, operative times of robotic cases continued to improve and approach laparoscopic times, similar to other robot-assisted procedures such as robot-assisted partial nephrectomy [26]. In this regard, it is not unreasonable to expect proficiency with RDN to improve with further cases and reach a level of mastery equivalent to that of LDN. With respect to training surgeons in surgical robotics, it has been previously demonstrated that surgeons with formal robotic training are able to perform robot-assisted cases immediately out of training at an equivalent level to experienced surgeons [27]. With regard to mastery, a previous study demonstrated that improvements in robotic-assisted procedures such as partial nephrectomy can still continue to improve up to 300 cases [28]. Our experience with donor nephrectomy shows that mastery may be achieved with significantly fewer cases as we approached standard laparoscopic donor nephrectomy operative times by the 22nd case. However, the pool of donors is limited and will result in a lower number of

Table 4 Donor postoperative complications

	LDN (*N* = 73)	RDN (*N* = 22)	*p*
Postoperative complications	4 (5.5)	2 (9.1)	0.542
Minor complications grade I–II	3 (4.1)	2 (9.1)	0.359
Fever	1 (1.4)	0	
Nausea	1 (1.4)	1 (4.5)	
Atelectasis	1 (1.4)	0	
Chylous leakage	0	1 (4.5)	
Major complications grade III–V	1 (1.4)	0	0.581
Grade IV complications			
Acute pulmonary edema	1 (1.4)	0	
Postoperative complications at 2 weeks	11 (15.1)	1 (4.5)	0.193
Minor complications grade I–II	11 (15.1)	1 (4.5)	
Nausea	2 (2.7)	0	
Abdominal/flank pain	4 (5.5)	0	
Chylous ascites	0	1 (4.5)	
Epididymitis	1 (1.4)	0	
Seroma	1 (1.4)	0	
Arm paresthesia	1 (1.4)	0	
Wound infection	1 (1.4)	0	
Diffuse rash	1 (1.4)	0	
Postoperative complications at 1 year	3 (4.1)	1 (4.5)	0.136
Minor complications grade I–II	3 (4.1)	1 (4.5)	
Nausea/dizziness	1 (1.4)	1 (4.5)	
Testicular soreness/swelling	2 (2.7)	0	

Table 5 Recipient outcomes

	LDN (*N* = 73)	RDN (*N* = 22)	*p*
Creatinine at 1 month	1.4 (0.6)	1.2 (0.5)	0.106
Creatinine at 6 months	1.2 (0.3)	1.2 (0.5)	0.532
Creatinine at 1 year	1.3 (0.4)	1.2 (0.5)	0.128
eGFR at 1 month	63.7 (27.2)	80.6 (47.5)	0.125
eGFR at 6 months	67.9 (29)	77.7 (48.8)	0.58
eGFR at 1 year	63.9 (23.6)	70.6 (26.1)	0.233
Delayed graft function	3 (4.1)	0	0.334
Graft failure	1 (1.4)	0	0.581

available donor nephrectomy cases, which may hinder complete mastery. For this reason, simulation may be a crucial tool for training novices. It has been previously reported that it may take 10 h of simulation training for residents to achieve surgical proficiency [29]. Cadavers could be another method of training. However, multidisciplinary cooperation is required for maximal efficiency of the expensive cadaver [30, 31]. The development of a surgical training model may also be useful in overcoming the learning curve for RDN, similar to the training model previously used in robot-assisted partial nephrectomy [32].

Although the operative time, WIT, and extraction time were longer in RDN group, we demonstrate that this does not translate into poorer recipient renal function. Recipient eGFR at 1 month, 6 months, and 1 year post-transplantation was shown to be comparable between the two groups. In addition, there were no cases of delayed graft function or graft failure of recipients receiving kidneys from donors undergoing RDN. A previous study also showed no differences in recipient renal function despite increases in WIT and extraction time [24]. It has also been demonstrated previously that WIT up to 720 s did not correlate with recipient graft function [33]. In all cases, the WIT was well under 720 s, with the maximum WIT in the RDN group being 390 s. We can further expect continued improvement in WIT as we performed more robotic cases after this initial experience. Despite increases in operative times, we also show on the donor side that postoperative renal function was not affected. eGFR was not different between the two groups postoperatively and at 2 weeks and 1 year follow-ups, suggesting that RDN does not negatively affect donor renal function compared to LDN.

The postoperative course, including hospital stay length, did not differ between the two groups. The rate of postoperative complications did not differ postoperatively, at 2 week follow-up and 1 year follow-up. It can also be noted that chylous ascites and leakage were two minor complications that appeared exclusively in the RDN group. These complications prompted further investigation and refinement in our surgical technique which materialized in the form of less fine dissection around the hilum, aorta, and vena cava. With less fine dissection, we were able to lower the likelihood of unintentional damage to the lymphatic vessels. Not only did this prevent future chylous leakage, it also allowed for the elimination of unnecessary actions and faster dissection in later cases. Thus, examination of exclusive complications in robotic cases is crucial for further refinement in the technique.

We acknowledge several limitations of this study. This is a retrospective review of a relatively small sample size of patients performed by a single surgeon. Data, such as cost, cosmesis, and pain, could not be obtained. Although reviewing patients from a single surgeon minimized surgical confounders, the learning curve of RDN shown in this study is from a surgeon with extensive experience in robotic and laparoscopic surgeries, and may not be representative of most surgeons learning RDN. Additional studies on the comparison between RDN and LDN at different stages of the learning curve may be done to resolve this issue. Similarly, the procedures being performed at different timeperiods could be affected by factors such as advancements in knowledge or technology. Although we have compared the longest postoperative courses of patients undergoing RDN and LDN so far, longer term studies may be needed to fully elicit the complete long-term differences between the two procedures.

Despite these limitations, this study has currently the longest postoperative follow-up for both donors and recipients, and demonstrates that RDN is a safe application of robotic surgery with comparable outcomes compared to LDN. Although longer operative time, WIT, and extraction time were initially associated with RDN, substantial improvements were made over the course of this early experience, and further advances can be expected after additional experience with RDN. These differences in time did not have a significant impact on postoperative donor renal function, donor complication rates, and recipient outcomes. Furthermore, the learning curve derived from our experience suggests that a surgeon learning RDN can quickly match LDN operative times.

Authors contribution Anthony Yang-author of the manuscript contributed to data collection, statistical analysis, and manuscript review. Naman Barman-contributed to study design, data collection, and manuscript review. Edward Chin-contributed to manuscript review. Daniel Herron contributed to manuscript review. Antonios Arvelakis contributed to manuscript review. Dianne LaPointe Rudow contributed to data collection and manuscript review. Sander S. Florman contributed to manuscript review. Michael A. Palese, Principal Investigator conducted the donor nephrectomies and contributed to study design and manuscript review.

Compliance with ethical standards

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Conflict of interest All authors (Anthony Yang, Naman Barman, Edward Chin, Daniel Herron, Antonios Arvelakis, Dianne LaPointe Rudow, Sander S. Florman, and Michael A. Palese) declare no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional review board at the Icahn School of Medicine at Mount Sinai and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent As determined by the institutional review board, informed consent was not required.

References

1. Ratner LE, Ciseck LJ, Moore RG, Cigarroa FG, Kaufman HS, Kavoussi LR (1995) Laparoscopic live donor nephrectomy. Transplantation 60(9):1047–1049
2. Yuan H, Liu L, Zheng S et al (2013) The safety and efficacy of laparoscopic donor nephrectomy for renal transplantation: an updated meta-analysis. Transplant Proc 45(1):65–76
3. Eroğlu A, Şener C, Tabandeh B, Tilif S, Okçuoğlu Kadıoğlu Z, Kaçar S (2013) Transvaginal laparoscopic donor nephrectomy. Transplant Proc 45(3):881–882
4. Tokuda N, Nakamura M, Tanaka M, Naito S (2001) Hand-assisted laparoscopic live donor nephrectomy using newly produced LAP DISC: initial three cases. J Endourol 15(6):571–574
5. Desai MM, Berger AK, Brandina R et al (2009) Laparoendoscopic single-site surgery: initial hundred patients. Urology 74(4):805–812
6. Horgan S, Vanuno D, Sileri P, Cicalese L, Benedetti E (2002) Robotic-assisted laparoscopic donor nephrectomy for kidney transplantation. Transplantation 73(9):1474–1479
7. Ratner LE, Buell JF, Kuo PC (2000) Laparoscopic donor nephrectomy: pro. Transplantation 70(10):1544–1546
8. Organ procurement and transplantation network. National Data—OPTN. https://optn.transplant.hrsa.gov/data. Accessed 11 Mar 2017
9. Palese MA, Stifelman MD, Munver R et al (2005) Robot-assisted laparoscopic dismembered pyeloplasty: a combined experience. J Endourol 19(3):382–386
10. Cohen AJ, Williams DS, Bohorquez H et al (2015) Robotic-assisted laparoscopic donor nephrectomy: decreasing length of stay. Ochsner J 15(1):19–24
11. Profanter C, Schmid T, Prommegger R, Bale R, Sauper T, Bodner J (2004) Robot-assisted mediastinal parathyroidectomy. Surg Endosc 18(5):868–870
12. Lin CY, Yang CR, Cheng CL et al (2014) Application in robotic urologic surgery. J Chin Med Assoc 77(5):242–245
13. Ho H, Schwentner C, Neururer R, Steiner H, Bartsch G, Peschel R (2009) Robotic-assisted laparoscopic partial nephrectomy: surgical technique and clinical outcomes at 1 year. BJU Int 103(5):663–668
14. Sood A, Jeong W, Peabody JO, Hemal AK, Menon M (2014) Robot-assisted radical prostatectomy: inching toward gold standard. Urol Clin North Am 41(4):473–484

15. Guru KA, Hussain A, Chandrasekhar R et al (2009) Current status of robot-assisted surgery in urology: a multi-national survey of 297 urologic surgeons. Can J Urol 16(4):4736–4741
16. Ghani KR, Sukumar S, Sammon JD, Rogers CG, Trinh QD, Menon M (2014) Practice patterns and outcomes of open and minimally invasive partial nephrectomy since the introduction of robotic partial nephrectomy: results from the nationwide inpatient sample. J Urol 191(4):907–912. doi:10.1016/j.juro.2013.10.099
17. Rosiek A, Leksowski K (2015) Technology advances in hospital practices: robotics in treatment of patients. Technol Cancer Res Treat 14(3):270–276
18. Herron DM, Marohn M, SAGES-MIRA Robotic Surgery Consensus Group (2008) A consensus document on robotic surgery. Surg Endosc 22(2):313–325
19. Tan A, Ashrafian H, Scott AJ et al (2016) Robotic surgery: disruptive innovation or unfulfilled promise? A systematic review and meta-analysis of the first 30 years. Surg Endosc 30(10):1–23
20. Giacomoni A, Di Sandro S, Lauterio A et al (2016) Robotic nephrectomy for living donation: surgical technique and literature systematic review. Am J Surg 211(6):1135–1142. doi:10.1016/j.amjsurg.2015.08.019
21. Cheng EY, Leeser DB, Kapur S, Del Pizzo J (2010) Outcomes of laparoscopic donor nephrectomy without intraoperative systemic heparinization. J Urol 183(6):2282–2286. doi:10.1016/j.juro.2010.02.027
22. Jacobs SC, Cho E, Foster C, Liao P, Bartlett ST (2004) Laparoscopic donor nephrectomy: the University of Maryland 6-year experience. J Urol 171(1):47–51
23. Mehrabi A, Wiesel M, Zeier M et al (2004) Results of renal transplantation using kidneys harvested from living donors at the University of Heidelberg. Nephrol Dial Transplant 19(SUPPL. 4):48–54
24. Bhattu AS, Ganpule A, Sabnis RB, Murali V, Mishra S, Desai M (2015) Robot-assisted laparoscopic donor nephrectomy vs standard laparoscopic donor nephrectomy: a prospective randomized comparative study. J Endourol 29(12):1334–1340
25. Haseebuddin M, Benway BM, Cabello JM, Bhayani SB (2010) Robot-assisted partial nephrectomy: evaluation of learning curve for an experienced renal surgeon. J Endourol 24(1):57–61
26. Lavery HJ, Small AC, Samadi DB, Palese MA (2011) Transition from laparoscopic to robotic partial nephrectomy: the learning curve for an experienced laparoscopic surgeon. JSLS 15(3):291–297
27. Taylor AS, Lee B, Rawal B, Thiel DD (2015) Impact of fellowship training on robotic-assisted laparoscopic partial nephrectomy: benchmarking perioperative safety and outcomes. J Robot Surg 9(2):125–130
28. Paulucci DJ, Abaza R, Eun DD, Hemal AK, Badani KK (2017) Robot-assisted partial nephrectomy: continued refinement of outcomes beyond the initial learning curve. BJU Int 119(5):748–754. doi:10.1111/bju.13709
29. Wiener S, Haddock P, Shichman S, Dorin R (2015) Construction of a urologic robotic surgery training curriculum: how many simulator sessions are required for residents to achieve proficiency? J Endourol 29(11):1289–1293
30. Huri E, Ezer M, Chan E (2016) The novel laparoscopic training 3D model in urology with surgical anatomic remarks: fresh-frozen cadaveric tissue. Turk J Urol 42(4):224–229
31. Blaschko SD, Brooks HM, Dhuy SM, Charest-Shell C, Clayman RV, McDougall EM (2007) Coordinated multiple cadaver use for minimally invasive surgical training. JSLS 11(4):403–407
32. Hung AJ, Ng CK, Patil MB et al (2012) Validation of a novel robotic-assisted partial nephrectomy surgical training model. BJU Int 110(6):870–874
33. Buzdon MM, Cho E, Jacobs SC, Jarrell B, Flowers JL (2003) Warm ischemia time does not correlate with recipient graft function in laparoscopic donor nephrectomy. Surg Endosc Other Interv Tech 17(5):746–749