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Xiaolong S Liu
Thomas Jefferson University

Hadley W Narins
Thomas Jefferson University

Warren R Maley
Thomas Jefferson University

Adam M Frank
Thomas Jefferson University

Costas D. Lallas
Thomas Jefferson University

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Robotic-Assistance Does Not Enhance Standard Laparoscopic Technique for Right-Sided Donor Nephrectomy

Xiaolong S. Liu, MD, Hadley W. Narins, BA, Warren R. Maley, MD,
Adam M. Frank, MD, Costas D. Lallas, MD

ABSTRACT

Objective: To examine donor and recipient outcomes after right-sided robotic-assisted laparoscopic donor nephrectomy (RALDN) compared with standard laparoscopic donor nephrectomy (LDN) and to determine whether robotic-assistance enhances LDN.

Materials & Methods: From December 2005 to January 2011, 25 patients underwent right-sided LDN or RALDN. An IRB-approved retrospective review was performed of both donor and recipient medical charts. Primary endpoints included both intraoperative and postoperative outcomes.

Results: Twenty right-sided LDNs and 5 RALDNs were performed during the study period. Neither estimated blood loss (76.4mL vs. 30mL, $P=.07$) nor operative time (231 min vs. 218 min, $P=.61$) were significantly different between either group (LDN vs. RALDN). Warm ischemia time for LDN was 2.6 min vs. 3.8 min for RALDN ($P=.44$). Donor postoperative serum estimated glomerular filtration rates (eGFR) were similar (53 vs. 59.6mL/min/1.73m², LDN vs. RALDN, $P=.26$). For the recipient patients, post-transplant eGFR were similar at 6 months (53.4 vs. 59.8mL/min/1.73m², LDN vs. RALDN, $P=.53$).

Conclusion: In this study, robotic-assistance did not improve outcomes associated with LDN. Larger prospective studies are needed to confirm any perceived benefit of RALDN.

Key Words: Robotic donor nephrectomy, Laparoscopic donor nephrectomy, Kidney transplant.

Department of Urology, Thomas Jefferson University, Philadelphia, Pennsylvania, USA (Drs. Liu, Narins, Lallas).

Thomas Jefferson University, Department of Surgery, Division of Transplantation Surgery, Philadelphia, Pennsylvania, USA (Drs. Maley, Frank).

Address correspondence to: Costas D. Lallas, MD, Associate Professor of Urology, Department of Urology, Thomas Jefferson University, Philadelphia, PA, USA. Telephone: (215) 955-6961, Fax (215) 923-1884, E-mail: costas.lallas@jefferson.edu

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INTRODUCTION

Laparoscopic donor nephrectomy (LDN) was first introduced in 1995 by Ratner and colleagues and has since demonstrated both low donor morbidity as well as excellent graft performance in recipient patients.¹⁻⁴ Other advantages of LDN include decreased postoperative narcotic requirements, lower intraoperative blood loss, shorter duration of postoperative hospital stay, and improved cosmetic results compared to that of conventional open procedures.⁵⁻⁸

Left-sided donor nephrectomy has been traditionally performed, because left kidneys were acknowledged as the preferred organ for transplantation while right-sided kidneys were reserved for instances where the left renal unit was deemed unacceptable for transplantation (eg, aberrant left-sided vascular anatomy or size discrepancy rendering the right kidney superior and thus more suitable for transplantation).^{9,10} Fear of a resultant short renal vein and renal vein graft thrombosis further dissuaded surgeons from performing right-sided harvests.^{11,12} However, several recent studies have demonstrated equivalent postoperative results between right- and left-sided LDN groups, leading to an increasing number of centers now performing right-sided LDN to maximize the donor pool regardless of left-sided anatomy.¹³⁻¹⁶

With the introduction of the da Vinci Robotic Surgical System (Intuitive Surgical, Sunnyvale, CA), robotic-assisted laparoscopic renal surgery has gained popularity, with the most popular procedures being radical and partial nephrectomy. The facility of dissection around the renal hilum provided by the robotic surgical system and its importance in donor nephrectomy led investigators to pursue robotic-assisted laparoscopic donor nephrectomy (RALDN), an operation that has been reported to be safe and successful for organ retrieval.^{17,18} However, these studies have mainly been limited to left-sided donor nephrectomy procedures.¹⁷ Also, no trials have compared outcomes between RALDN and LDN techniques. In this study, we report the donor and recipient outcomes of our right-sided RALDN patients with comparison analysis to the standard LDN technique.

MATERIALS AND METHODS

Following IRB approval, a retrospective medical chart review of all donor and matched recipients was performed. Preoperative patient characteristics including age at time of surgery and BMI were recorded for all donor and recipient pairs. Donor renal vascular anatomy was assessed preoperatively with fine cut contrast enhanced computed tomography that included 3-dimensional reconstructions. Intraoperative and postoperative data were then subsequently collected. Primary endpoints included estimated blood loss (EBL), operative duration (time starting at patient positioning and ending with transportation out of the operating room), warm ischemia time (WIT, defined as time from clamping of the renal artery to perfusion with preservation medium), occurrence of any intraoperative complications, donor estimated glomerular filtration rates (eGFR) at hospital discharge, total postoperative narcotic pain requirement, and length of hospital stay (LOS). Estimated glomerular filtration rates were calculated using the modification of diet in renal disease formula based on patient age in years, gender, race, and serum creatinine in mg/dL and reported in mL/min/1.73m².

All postoperative intravenous and oral narcotic pain medication use was tallied and reported as a total oral morphine equivalent dose (MED) in milligrams (mg) using a validated on-line calculator (<http://www.globalrph.com/narcoticonv.htm>).

For recipients, 1-week, 6-month, and 1-year posttransplant serum creatinine levels were collected and eGFRs were calculated. Any diagnosis of delayed graft function, defined by anuria within the first 24 hours or need for postoperative hemodialysis within one week, was noted from the medical history.

All RALDNs were performed by a single urologic surgeon using the da Vinci Robotic Surgical System. As with LDN, patient positioning for RALDN was a modified 45° flank, and the procedure was begun with placement of a hand port through which pneumoperitoneum was established. The hand port was not used for the dissection, but was available for graft removal and in the case of any emergencies. One extra working port was placed for RALDN, an assistant port used for passage of a vascular stapler. The approach to the dissection for RALDN did not differ significantly from LDN. Finally, in our robotic procedures, renal graft hilar vessels were ligated by the assistant using an endovascular stapler passed through the aforementioned accessory port. LDNs were performed by both this

same urologic surgeon as well as 2 surgeons from the Division of Transplantation Surgery in the Department of Surgery at our institution. Surgical technique for LDN differed slightly for each surgeon, but all involved initial placement of a hand port for dissection and graft removal, and ligation of the renal vessels with an endovascular stapler. Surgeons from the aforementioned transplantation division performed all recipient surgeries.

Data points are reported as a mean or percentage where appropriate. Two-tailed unpaired *t* tests and Fisher's exact tests were implemented to calculate statistical significance (defined as a P-value ≤.05, GraphPad Prism Version 5.03, GraphPad Software 2236, Avenida de la Playa La Jolla, CA).

RESULTS

Between December 2005 and January 2011, 160 minimally invasive living donor nephrectomies were performed at our institution. Of these, 135 were left-sided and 25 (16%) were right-sided. Twenty-five matched recipient patients underwent kidney transplantation utilizing the donated right kidney obtained from the LDN and RALDN groups. Patient and recipient demographics are reported in **Table 1**. Mean patient ages between the 2 groups were similar

Table 1.
Donor and Recipient Patient Demographics

	LDN ^a (n=20)	RALDN ^a (n=5)	P Value
Donors			
Age (years)	40.7	34.8	.20
BMI ^a	25.3	31.2	.01
Preoperative creatinine (mg/dL)	0.8	0.9	.64
Preoperative eGFR (mL/min/ 1.73m ²)	88.7	93.4	.65
Units with >1 Renal Artery	1	0	.63
Units with >1 Renal Vein	2	0	.48
Recipients			
Age (years)	49.2	41.6	.53
BMI ^a	25	29.6	.04
Preoperative creatinine (mg/dL)	7.0	8.3	.42
Preoperative eGFR (mL/min/ 1.73 m ²)	9.4	8.0	.44

^aLDN – Laparoscopic Donor Nephrectomy, eGFR – estimated glomerular filtration rate, RALDN – Robotic-assisted Laparoscopic Donor Nephrectomy, BMI – Body Mass Index.

(40.7 years vs. 34.8 years, $P=.20$), while BMI was higher in the RALDN group (31.2 vs. 25.3, $P=.01$). Two donor kidneys in the LDN group had 2 renal veins while one kidney had 2 renal arteries. All other grafts contained a single renal artery and vein without evidence of other complex vascular anatomy. In the RALDN group, all harvested renal grafts had a single renal artery and a single renal vein. Preoperative donor serum creatinine (0.8 vs. 0.9 mg/dL, $P=.64$) and eGFR values (88.7 vs. 93.4 mL/min/1.73m², $P=.65$) were not significantly different between the 2 groups.

EBL, WIT, and total operative time are reported in **Table 2**. EBL was 76.4mL for LDN and 30mL for RALDN, but the difference did not reach statistical significance ($P=.07$). Mean WIT was 2.6 minutes for LDN (n=15) vs. 3.8 minutes for RALDN (n=4), $P=.44$. Operative times were available for 17 of 20 LDN cases and 4 of 5 RALDN cases. Mean operative time for LDN was 231 minutes while for RALDN it was 218 minutes, $P=.61$. No intraoperative complications occurred in either group nor were there any conversions to open surgery.

Postoperative endpoints included donor renal function at discharge, total MED requirement, and LOS (**Table 2**). The mean serum creatinine value (1.3mg/dL for both) and mean eGFR (53 vs. 59.6mL/min/1.73m², LDN vs. RALDN) were similar for both donor groups by day of discharge. One patient in the RALDN group with a prior history of heavy preoperative narcotic requirements was excluded from the postoperative narcotic data pool. The remaining 24 patients were included in the MED analysis that found

a similar narcotic use for both groups (93.5mg vs. 94.6mg for LDN vs. RALDN respectively, $P=.97$). LOS was 1 day shorter in duration for LDN at 2.6 days vs. 3.6 days for RALDN ($P=.19$).

Recipient age at the time of surgery (49.2 vs. 41.6 years, $P=.53$) and preoperative creatinine (7.0 vs. 8.3mg/dL, $P=.42$) and eGFR (9.4 vs. 8.0mL/min/1.73 m², $P=.44$) were similar between those receiving grafts from LDN and RALDN donors (**Table 1**). The average BMI was higher for those in the RALDN recipient group (29.6 vs. 25, $P=.04$). Serum creatinine values at 1 week posttransplant was higher (3.1 mg/dL, n=4) vs LDN (1.8mg/dL) and estimated GFR lower for those who underwent RALDN (36.8mL/min/1.73 m², n=4) vs. LDN (45.7mL/min/1.73m²), but neither reached statistical significance, $P=.17$ and $.26$, respectively (**Table 3**). At 6 months, this disparity was less apparent with serum creatinine values of 1.4mg/dL for LDN and 1.5mg/dL for RALDN, $P=.87$, and eGFRs of 53.4mL/min/1.73 m² for LDN (n=14) and 59.8mL/min/1.73m² for RALDN (n=4), $P=.53$. After 1 year, recipient creatinine values were similar for both groups (1.6 vs 1.4mg/dL, LDN vs RALDN, $P=.50$), and recipient eGFR was higher for RALDN 60.8 vs. 44.3mL/min/1.73m² for LDN, $P=.05$. In each group, only one recipient had a postoperative diagnosis of delayed graft function (5% vs. 20%, LDN vs. RALDN, $P=.37$).

DISCUSSION

Renal transplantation is the best treatment available for end-stage renal disease. Living renal transplantation has

Table 2.
Donor Outcomes

	LDN ^a	RALDN ^a	P Value
EBL ^a (mL)	76.4	30	.07
OR Time (min)	231, n=17	218, n=4	.61
WIT ^a (min)	2.6, n=15	3.8, n=4	.44
MED ^a (mg)	93.5	94.6, n=4	.97
LOS ^a (days)	2.6	3.6	.19
Postoperative Creatinine at Discharge (mg/dL)	1.3	1.3	.84
Postoperative eGFR (mL/min/1.73m ²)	53	59.6	.26

^aLDN – Laparoscopic Donor Nephrectomy; RALDN – Robotic-assisted Laparoscopic Donor Nephrectomy; EBL – Estimated Blood Loss; WIT – Warm Ischemia Time; MED – Morphine Equivalent Dose; LOS – Length of Stay; eGFR – estimated glomerular filtration rate.

Table 3.
Recipient Outcomes

	LDN ^a	RALDN ^a	P Value
Posttransplant Creatinine (mg/dL) and Posttransplant eGFR ^a (mL/min/1.73m ²)			
1 week Creatinine	1.8	3.1, n=4	.17
1 week eGFR	45.7	36.8, n=4	.26
6 months Creatinine	1.4, n=14	1.5, n=4	.87
6 months eGFR	53.4, n=14	59.8, n=4	.53
1 year Creatinine	1.6, n=9	1.4	.50
1 year eGFR	44.3, n=9	60.8	.05
DGF ^a	1/20	1/5	.37

^aLDN – Laparoscopic Donor Nephrectomy; RALDN – Robotic-assisted Laparoscopic Donor Nephrectomy; DGF – Delayed Graft Function; eGFR – estimated glomerular filtration rate.

greatly expanded the number of kidneys available for the donor pool.¹⁹ Laparoscopic donor nephrectomy has become the gold standard procedure for those who wish to be living kidney donors.²⁰ The operation has been proven to be technically feasible and demonstrates outcomes clinically comparable to those of open procedures.⁵ In addition, right-sided donor nephrectomy has also been shown to be equally efficacious in comparison to traditional left-sided harvests.¹⁶

RALDN is a technical variation of LDN that may provide for a shorter learning curve compared to that of standard laparoscopic nephrectomy.²¹⁻²³ While the concern of utilizing LDN for retrieval of right-sided kidneys resulting in short renal veins leading to increased incidence of thrombosis and graft loss has been well documented, the advantages of robotic-assisted procedures have been suggested as a conduit to overcome the technical barriers associated with standard laparoscopy.¹⁸ Robotic systems are theorized to improve upon the limitations of pure laparoscopic surgery by providing enhanced visibility and flexibility as well as 3-dimensional vision with superior dexterity which provides for more efficient dissection of the renal hilum.²³

Advantages of robotic-assisted techniques should theoretically translate into improved donor and recipient outcomes compared to LDN outcomes. We hypothesized that robotic-assistance may lead to lower blood loss, shorter operative times, and improved recipient outcomes. Because of our extensive prior experience with robotic renal surgery, we were comfortable with our patient and port positioning and did not have to overcome these aspects of the learning curve for this relatively high-stakes procedure. We primarily focused on right-sided RALDN, because we felt that autonomous dissection of the right kidney, particularly the upper pole and absence of accessory venous systems (ie, no lumbar vein or adrenal vein to identify or dissect), was easier compared to the left and thus was a more appropriate side on which to attempt our initial robotic-assisted donor nephrectomy procedures. If we had been able to demonstrate a significant positive impact of robotic-assistance, we would have proceeded to attempt left-sided robotic donor nephrectomies, with its higher colonic flexure and more complex accessory venous system.

In our study, EBL and OR times, 2 of the theorized goal outcomes associated with robotic surgery, showed improvement, but these results did not reach statistical significance. Alternatively, LOS and recipient eGFR at discharge were slightly worse with RALDN, although these

results also did not reach statistical significance. Although serum creatinine levels were similar for both recipient groups at 1 year, when calculating the eGFR, recipients at 1 year posttransplant was significantly higher for RALDN patients compared to LDN. In view of the comparable serum creatinine levels and when considering our relatively small numbers, these results are difficult to interpret as being a true indication of more durable results with RALDN over LDN. It must be stressed that short-term intraoperative factors, such as EBL, OR time, and WIT, showed no benefit. Other clinical outcomes, including postoperative narcotic requirements as well as postoperative donor eGFR values were not significantly different between LDN and RALDN, demonstrating equal feasibility between both techniques (**Tables 2 and 3**). In all patients, the operation was kept minimally invasive. There were no intraoperative complications including bleeding or bowel injuries, which can be associated with laparoscopic surgery.^{24,25} Understandably, these results may have been influenced by our young donor population with relatively low BMIs and low renal vascular complexity. In fact, our patient group had a lower incidence of dual vessels than the series published by Fettouh et al²⁶ who reported on 79 patients, approximately 20% of whom had multiple renal arteries or veins. However, their complication rate was also very low and their mean EBL was 65mL, demonstrating that LDN can be safe even for donors with vascular anomalies.

The increased WIT in our RALDN group is undoubtedly related to the inefficacy of hilar control with extirpative robotic renal surgery. At the time of this manuscript's writing, the da Vinci Robotic Surgical System does not yet have a stapler attachment, leaving the only devices for hilar control for the robotic surgeon to be either suture ligation or Hem-o-lok clip application, 2 methods that we believe to be unacceptably inferior. As a result, at the time of vessel ligation during RALDN, we had an assistant pass a vascular stapler through an accessory port to ligate the renal artery and vein, a process that was admittedly more awkward than with the laparoscopic counterpart, and thus may have translated into longer WITs. However, this difference did not reach statistical significance in our study nor did it adversely affect recipient allograft function. In addition, our results compare favorably to RALDNs performed by Hubert et al¹⁹ that showed an average WIT of 5.8 minutes in their cohort of patients. Still, in our study there was no improvement in the incidence of delayed graft function between the 2 groups, which occurred only once in either patient population.

Finally, the higher costs associated with robotics should be a determining factor when evaluating surgical techniques utilized in urologic surgery.²⁷ When laparoscopic radical nephrectomy has been compared with open procedures, studies have shown that laparoscopy contributes an approximate \$2000 to total hospital costs.²⁸ A financial analysis specific to robotic surgery demonstrated that robotic-assistance incurs an additional \$3200 in total hospital care dollars.²⁹ These extra costs may be driven down if postoperative patient expenses can be reduced or if return to normal activity is faster. As robotic-assistance did not significantly improve postoperative patient parameters in our study, the higher costs associated with the use of robotics in our era of health-care financial awareness is another significant determining factor against RALDN.

Our study has several limitations that must be acknowledged. First, our low absolute number of patients can limit the demonstration of benefit of robotic-assisted donor nephrectomy. However, the absolute percentage of right-sided donor nephrectomies performed at our institution (16%) far exceeds the reported percentage of right-sided LDNs at several other major transplant centers in the United States.³⁰ A larger number of study patients may drive some factors that did not reach statistical significance in our study to eventually show a difference between the 2 techniques. Second, a retrospective design inherently introduces selection bias in the study groups. Third, the theoretical advantages of RALDN over LDN during laparoscopic dissection may be better displayed in donor patients with complex renal vascular anatomy. In our study population, no donor patient in the RALDN group had >1 renal artery or vein. Patients with multiple renal vessels may be better suited for RALDN secondary to more efficient dissection of the renal pedicles compared to LDN, possibly leading to significantly shorter OR times or less EBL. Additionally, the addition of more advanced robotic surgical instrumentation, such as an endovascular stapler, may have a positive influence on some of the primary endpoints in our study. Finally, postoperative complications, such as deep vein thrombosis, pulmonary embolism, urinary tract infection, or wound infections were not reported in either group. Although these are generally limited in healthy donor patients undergoing minimally invasive surgery, subtle differences between RALDN and LDN may impact any or all of these factors.

CONCLUSION

Right-sided living donor nephrectomy with either standard laparoscopic or robotic-assisted techniques is tech-

nically feasible and safe, demonstrating similar donor and recipient outcomes, with slightly better recipient eGFR at 1 year for RALDN. Our study, however, did not prove many of the perceived benefits with the addition of robotic-assistance to LDN. More advanced robotic technology and instrumentation will likely attract further evaluation of RALDN. Future prospective studies with a larger number of patients may better elucidate the potential benefit of a robotic-assisted approach during minimally invasive donor nephrectomy.

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