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Effective and safe implementation of robot-assisted donor nephrectomy by experienced laparoscopic surgeons

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Abstract

Background: In June 2021, the first robot-assisted donor nephrectomy (RADN) was performed at the Leiden University Medical Center (LUMC), the Netherlands. The goal of this study was to investigate whether this procedure has been implemented safely and efficiently.

Methods: RADN was retrospectively compared to laparoscopic donor nephrectomy (LDN) performed during the same time period (June 2021 until November 2022). Patients were assigned to RADN depending on the availability of the da Vinci robot and surgical team. The studied endpoints were postoperative complications, operative time, estimated blood loss, warm ischemic time (WIT), and postoperative pain experience. For analysis, the Student's *t*-test and Chi-squared test were used for, respectively, continuous and categorical data.

Results: Forty RADN were compared to 63 LDN. Total insufflation time was significantly longer in RADN compared to LDN (188 min (169–214) versus 172 min (144–194); $p = 0.02$). Additionally, WIT was also found to be significantly higher in the robot-assisted group (04:54 min vs. 04:07 min; $p < 0.01$). No statistical differences were found in postoperative outcomes (eGFR of the recipient at 3-month follow-up, RADN 54.08 mL/min ±18.79 vs. LDN 56.41 mL/min ±16.82; $p = 0.52$), pain experience, and complication rate.

Conclusion: RADN was safely and efficiently implemented at the LUMC. It's results were not inferior to laparoscopic donor nephrectomy. Operative time and warm ischemic times were longer in RADN. This may relate to a learning curve effect. No clinically relevant effect on postoperative outcomes was observed.

KEYWORDS

donor nephrectomy, living donation, minimal invasive surgical procedures, robotic surgery

1 | INTRODUCTION

Live kidney donation can only be performed with a healthy donor who willingly undergoes surgery for the benefit of a patient with kidney failure. Therefore, safety of this procedure is of utmost importance. The development of minimal invasive surgical techniques has made a tremendous impact on the wellbeing of these live kidney donors with smaller incisions, less wound herniation, and less pain.[1]

In 1995, the first laparoscopic donor nephrectomy (LDN) was performed.[2] From that moment onwards, different studies have proven that laparoscopic procedures result in better outcomes regarding patient comfort and duration of hospital stay compared to open procedures.[3–5] The strive for further improving kidney donor surgical procedures and outcomes has led to the first robot-assisted donor nephrectomy (RADN) in 2001.[6] Many surgeons and institutes have now implemented this procedure to their armamentarium.

Robot-assisted surgery has been applied for an increasing spectrum of surgical procedures since its introduction. The three-dimensional view, excellent rotation possibilities of the instruments, and the absence of a tremor are important improvements compared to the laparoscopic procedure.[6] Existing literature provides evidence on the safety and efficacy of RADN compared to the conventional LDN, nevertheless, the superior beneficial value of RADN over LDN has not yet been established. Well performed randomized controlled trials and meta-analyses are limited.[7–14] When implementing this new technique, one should be aware of the learning curve, which indicates longer operative times for the first RADN procedures; however, these times can improve over time.[8,15,16]

At the Leiden University Medical Center (LUMC) Transplant Center, Leiden, the Netherlands, kidney, liver, (kidney) pancreas and islet of Langerhans transplantations are regularly performed. The annual number of live donor nephrectomies is about 80. From the beginning of 1966 to August 2022, 1472 living donor kidney transplantations have been performed. From the start until after 2010, donation procedures were performed by using the open or mini-open technique.[17] In 2009 the LDN procedure was implemented and gradually overtook open surgery as the gold standard.[18,19] In 2021, our center started with RADN. Our aim was to evaluate the outcomes of the first 40 RADNs compared to the LDNs performed at our center during the similar period.

2 | MATERIAL AND METHODS

2.1 | Patients

This study was approved by the institutional review board (METC 2022-050) and informed consent was obtained from the participants. The first 40 robot-assisted donor nephrectomies (RADN) were included, all performed between June 16th, 2021 and November 11th, 2022 at the LUMC, the Netherlands, performed by two DaVinci certified surgeons (H.D Lam, surgeon A and V.A.L. Huurman, surgeon B). The surgeons have extensive experience in laparoscopic donor nephrectomy without prior surgical experience in robotic DaVinci operations. They underwent extensive training as prescribed by the DaVinci company and a 2-year long preparation before the first case (e-learning test, simulation, onsite 2-day training at OSRI institute (Belgium) and at least 5 visits to a high-volume center (UZ Gent, Belgium, and UMC Amsterdam, the Netherlands)). The proctor was present for the first 2 cases. Patients eligible for a living donor nephrectomy were included as per the LUMC protocol; there were no selection criteria to assign donors to either the laparoscopic or robot-assisted procedure. Patients were assigned to the robot-assisted procedure if their surgery was planned on Thursday due to the availability of the DaVinci robot and depending on the presence of a DaVinci surgical team. Preoperatively, imaging of the kidney and vascularization was performed using computed tomography–angiography. All candidates were informed on a possible conversion to a hand-assisted, laparoscopic, or open approach in the case of adverse events. Follow up was completed at 3 months post-donation and included in the study. The three-month follow-up consisted of eGFR and creatinine measurements for renal function. The controls were laparoscopic donor nephrectomies (LDN) performed during the same aforementioned period.

2.2 | Surgical method

Since June 2021, the LUMC in the Netherlands implemented RADN. All RADNs were performed with the da Vinci® Xi Surgical System (Intuitive Surgical Inc, Sunnyvale CA, USA).

Both LDN and RADN procedures were performed with the donor under general anesthesia and placed in lateral right and left decubitus position for a left or right kidney donation, respectively. For LDN a subcostal mid-axillary open introduction of a 12 mm trocar port was made into the abdominal cavity. The abdomen was insufflated to 12 cm H2O carbon dioxide pressure, and a 30° camera was inserted. The second trocar was placed between the umbilicus and the xiphoid process in the midline. A third trocar was placed roughly equidistant from the umbilicus and the anterior superior iliac spine. The last 5 mm trocar was placed in the flank in the midaxillary line at the level of the umbilicus (Figure 1).

For RADN the trocars were placed in a concave curve to create a top view. A 5 cm transversal incision was made at the level of spina iliaca anterior for the

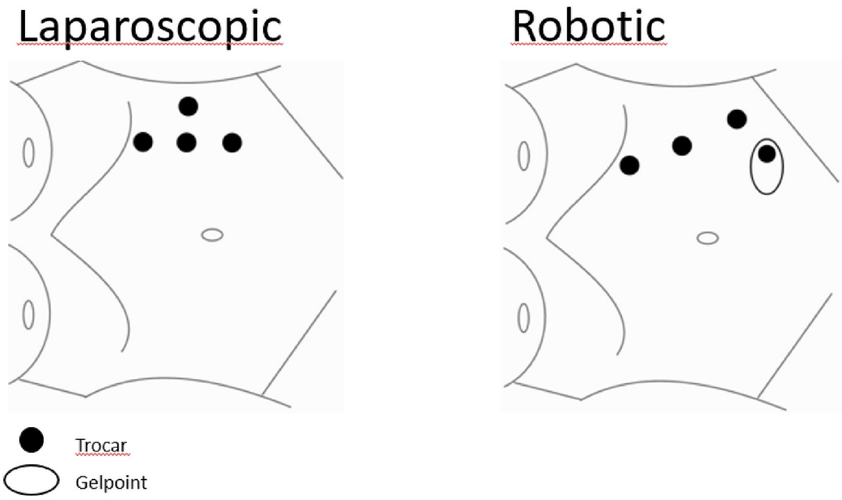

FIGURE 1 Laparoscopic and robotic trocar set-up. [Colour figure can be viewed at wileyonlinelibrary.com]

gelport (Alexis O Wound Protector-Retractor; Applied Medical, Salzburg, Austria). The gelport held a robot trocar and a 12 mm trocar for the assistant at 1 and 5 o'clock orientation, respectively. Next, three additional 8 mm robot trocars were introduced in a straight line connecting the 1 o'clock trocar to left hypochonder at 8 cm apart after pneumoperitoneum was created. A 30° camera was used. The da Vinci® Surgical System was then positioned laterally at the backside of the donor, and docking of the robot was performed by the table surgeon before the control was given to the console surgeon (Figure 1).

The surgical dissection was similar for both techniques. The descending colon was mobilized and displaced medially to facilitate opening of Gerota's fascia and division of the perirenal fat. The ureter was identified, clipped and dissected circumferentially at the level of the common iliac artery. The lateral region and posterior region of the kidney were dissected. The renal vein was identified and all its branches (if applicable i.e. in left donor nephrectomy the lumbar, gonadal and adrenal vein) were clipped and transected. Subsequently, the renal artery was identified and dissected free up to the level of the aortic origin. The renal artery and vein were divided using an endoscopic stapler (EndoGIA; US Surgical, Norwalk, USA) or powered stapler (Signia™ stapling system; Medtronic, Minneapolis, USA). The kidney was placed in the endobag (Endocatch; US surgical, Norwalk, USA) and extracted through a 6–8 cm Pfannenstiel incision in LDN and via the gelport in RADN. The kidney was flushed at the back-table with cold Custodiol® HTK Solution (Essential Pharmaceuticals LLC, Durham, USA). Meanwhile, the renal bed and vascular stumps were inspected, and any oozing or bleeding was controlled. Afterward all trocars were removed under direct vision, and fascia closure of the extraction site and 12 mm trocar ports was performed.[8] Local anesthesia (ropivacaine 7.5% 15–20cc) was injected near the trocar wounds as found appropriate by the surgeon.

2.3 | Data collection

Data was collected from the electronic patient file. The studied endpoints included postoperative complications according to the Clavien–Dindo classification,[20] which were then quantified using the Comprehensive Complication Index,[21] total operative time (min), total insufflation time (min), warm ischemic time (WIT) (min), estimated blood loss (mL), conversion to another surgical technique, length of hospital stay, pain measured by the VAS-score at different days after the surgery, creatinine and eGFR (CKD-EPI) (mL/min) of the donor at baseline and 3-month follow-up, and the eGFR (CKD-EPI) (mL/min) of the recipient at 3-month follow-up. Postoperative complications are defined as any complication within 30 days of the surgery. Total operative time is defined as the moment from the first incision until the skin closure. The total insufflation time is the length of the abdominal CO_2 insufflation time. WIT starts when the perfusion stops in the organ due to arterial clamping and stops when the kidney is cold flushed with preservation fluid. Conversion is defined as converting to hand-assisted or open procedure. Furthermore, technical difficulties and the infiltration of the surgical sites with ropivacaine were documented.

2.4 | Statistical analysis

Continuous variables were depicted as mean and standard deviation if following normal distribution, otherwise they were depicted as median and interquartile range (IQL). These variables were analyzed using the Student's *t*-test or Mann Whitney *U* test if they did not follow normal distribution. The categorical variables are listed as absolute numbers and percentages and have been analyzed using the Chi-squared test. The Pearson correlation was used to calculate the learning curve. The graph was produced using a linear regression. Statistical analyses were performed using IBM SPSS Statistics, version 27.0. A *p*-value less than 0.05 was considered statistically significant.

3 | RESULTS

Forty donors with a RADN were included in this study, 21 procedures were performed by surgeon A, and 19 procedures were performed by surgeon B. During the same period, 63 LDN were performed by 6 experienced surgeons. Preoperative donor characteristics are provided in Table 1. The median age was 56 and 53 years for RADN and LDN donors, respectively ($p = 0.90$). There was no difference in frequency of prior abdominal surgeries ($p = 0.65$). These were all minor surgeries, such as an appendectomy, cholecystectomy, cesarean section, and hernia correction. Baseline characteristics did not differ between RADN and LDN (Table 1).

3.1 | Intra-operative results

Intra-operative results were similar for RADN and LDN, except total operative time (227 min (203–249) versus 195 min (172–226); $p < 0.01$), total insufflation time (188 min (169–214) versus 172 min (144–194); $p = 0.02$), and WIT (04:54 min (04:00–05:28) versus 04:07 min (03:17–04:59); $p < 0.01$) favoring LDN (Table 2). A significant difference was found for the local infiltration with ropivacaine, as this was more often applied for RADN (87.5%) than LDN (33.3%; $p < 0.01$).

A conversion to an open procedure occurred once with RADN due to difficult exposure of the kidney. Once, there was a conversion from LDN to hand-assistance due to bleeding of the arterial staple line.

Other technical difficulties encountered during surgery were interference of the two robotic arms requiring re-docking of the robot, one stapler failure, and an error message of the DaVinci for incomplete charging of the

TABLE 1 Pre-operative donor characteristics.

	Robot-assisted donor nephrectomy (*N* = 40)	Laparoscopic donor nephrectomy (*N* = 63)	
Sex			$p = 0.87$
Male	19 (47.5%)[a]	31 (49.2%)	
Age (y)	56 (41.25–64.50)[b]	53 (46.00–60.00)	$p = 0.90$
BMI (m/kg^2)	26.04 ± 3.41[c]	26.01 ± 3.23	$p = 0.97$
ASA score			$p = 0.48$
I	20 (50.0%)	33 (52.4%)	
II	20 (50.0%)	28 (44.4%)	
III	0	2 (3.2%)	
Side nephrectomy			$p = 0.92$
Left	34 (85.0%)	54 (85.7%)	
Number of arteries			$p = 0.50$
1	33 (82.5%)	49 (77.8%)	
2	7 (17.5%)	12 (19.0%)	
3	0	2 (3.2%)	
Creatinine donor pre-operative (mcmol/L)	71.43 ± 13.57	73.75 ± 14.45	$p = 0.42$
eGFR donor pre-operative (mL/min)	87.00 ± 6.80	85.17 ± 8.22	$p = 0.24$
Prior abdominal surgery			$p = 0.65$
Yes	11 (27.5%)	20 (31.7%)	

[a]Absolute number (percentage)—Chi squared test.
[b]Median (Interquartile range)—Mann Whitney *U* test.
[c]Mean ± standard deviation—Student's *t* test.

TABLE 2 Intra-operative donor outcomes.

	Robot-assisted donor nephrectomy ($N = 40$)	Laparoscopic donor nephrectomy ($N = 63$)	
Total operative time (min)	227 (203–249)[a]	195 (172–226)	$p < 0.01$
Total insufflation time (min)	188 (169–214) Missing $N = 6$ (15.0%)	172 (144–194) Missing $N = 9$ (14.3%)	$p = 0.02$
Warm ischemic time (min:sec)	04:54 (04:00–05:28)	04:07 (03:17–04:59) Missing $N = 2$ (3.2%)	$p < 0.01$
Estimated blood loss (mL)	50 (0–150)	50 (0–100)	$p = 0.44$
Conversion to other technique	1 (2.5%)[b]	1 (1.6%)	$p = 0.74$
Local infiltration with ropivacaine 7.5%			$p < 0.01$
Yes	35 (87.5%)	21 (33.3%)	
No	5 (12.5%)	34 (54.0%) Missing $N = 8$ (12.7%)	

[a]Median (Interquartile range)—Mann Whitney U test.
[b]Absolute number (percentage)—Chi squared test.

spare battery which was resolved after contacting the DaVinci help center.

3.2 | Postoperative results

No significant differences were found for postoperative outcomes of kidney function in the donor and recipient, length of hospital stay, pain scores given as VAS-scores, Clavien–Dindo classification, and the CCI (Table 3).

There were four postoperative complications in the RADN group and five in the LDN group. In the RADN group, there were two cases of postoperative bleeding, one of which originated from the staple line and one did not have a clear focus. One bleed warranted a surgical intervention. That same patient suffered from pneumonia. One patient had a wound infection of the extraction site, for which oral antibiotics were prescribed. Complications resulting from the LDN included one case of persistent abdominal pain requiring a wound exploration, 1 fever, 1 atelectasis (on chest X-ray) and 1 conjunctivitis for which eye drops were prescribed. One patient suffered from bladder retention, which warranted temporary bladder catheterization.

3.3 | Subanalysis

The total operative time for surgeon A and B are depicted ($N = 40$; surgeon A $N = 21$, and surgeon B $N = 19$), demonstrating a reduction in operative time over time (surgeon A −0.209; $p = 0.36$, surgeon B −0.179; $p = 0.46$) (Table 4, Figure 2) (Appendix A).

A sub-analysis was done for surgeon A and B, comparing their combined LDN (total $N = 18$; surgeon A, $N = 9$ and surgeon B, $N = 9$) to their RADN ($N = 40$) (Appendix A). No significant differences were found for the intra-operative outcomes, except for a longer operative time for RADN compared to LDN (227 min (203–249) versus 175 min (160–213); $p < 0.01$), insufflation time (188 min (169–214) versus 159 min (135–189); $p = 0.01$), and WIT (04:54 min (04:00–05:28) versus 03:58 min (02:59–4:56); $p = 0.04$).

4 | DISCUSSION

The study demonstrated that RADN is effective and has been safely implemented with minor differences compared to LDN. Both operative time and insufflation time were longer in RADN, consistent with existing literature.[8–10,13,22] Previous research studies show that BMI, male, and multiple anatomy of the arteries may prolong the surgery time.[23,24] In our study, these factors did not differ between LDN and RADN. Moreover, it is expected that surgeons go through a learning curve for robot-assisted surgery.[8,15,16] Both surgeons demonstrated prolonged duration of RADN compared to LDN. This decreased with more experience almost matching their LDN operation time in the end. Nonetheless, the correlation between total operative time and number of procedures is not yet significant; this could either mean that the surgeons may have already overcome their learning curve due to their preexistent experience with LDN, or a larger sample size ($N = 26$) is needed, as studied by Takagi et al.[16]

Another significant difference was the longer WIT in RADN compared to LDN. This difference was not clinically relevant for outcomes of the kidney since there was no significant difference in outcomes of eGFR of the recipients 3 months after receiving the kidney.

Similarly, the infiltration of the surgical site with ropivacaine differed significantly between the RADN and LDN procedures. Infiltration with ropivacaine is a personal choice for each surgeon. Nevertheless, there

TABLE 3 Postoperative outcomes.

	Robot-assisted donor nephrectomy (*N* = 40)	Laparoscopic donor nephrectomy (*N* = 63)	
Length of hospital stay (d)	3.0 (2.0–3.0)[a]	3.0 (2.0–3.0)	$p = 0.27$
Time until defecation (d)	2 (2–2.75) Missing *N* = 14 (35.0%)	2 (2–3) Missing *N* = 28 (44.4%)	$p = 0.19$
VAS-score surgery day	5.35 ± 1.93[b]	5.42 ± 2.23	$p = 0.86$
VAS-score day 1 post-operative	4.35 ± 2.14	4.29 ± 2.09	$p = 0.88$
VAS-score day 2 post-operative	3.05 ± 2.32 Missing *N* = 1 (2.5%)	3.93 ± 2.25 Missing *N* = 3 (4.8%)	$p = 0.07$
VAS-score day 3 post-operative	2.18 ± 1.70 Missing *N* = 23 (57.5%)	3.25 ± 2.45 Missing *N* = 27 (42.9%)	$p = 0.11$
Clavien dindo			$p = 0.93$
I	1 (2.5%)[c]	2 (5.0%)	
II	1 (2.5%)	1 (2.5%)	
IIIa	1 (2.5%)	1 (2.5%)	
IIIb	1 (2.5%)	1 (2.5%)	
Comprehensive complication index (CCI)	0 (0–0)	0 (0–0)	$p = 0.95$
Creatinine donor post-operative, day after procedure (mcmol/L)	111.48 ± 23.11	114.90 ± 22.21	$p = 0.45$
Δ creatinine donor (%) (pre-op vs. post-op)	56.16 ± 14.18	56.85 ± 19.23	$p = 0.85$
Creatinine donor post-operative, 3 months follow-up (mcmol/L)	105.75 ± 19.61	112.71 ± 23.68	$p = 0.13$
Δ creatinine donor (%) (pre-op vs. 3 months post-op)	48.83 ± 13.74	53.11 ± 16.54	$p = 0.18$
eGFR donor post-operative, 3 months follow-up (mL/min)	58.95 ± 11.52	57.94 ± 12.51	$p = 0.68$
eGFR recipient post-operative, 3 follow-up (mL/min)	54.08 ± 18.79 Missing *N* = 2 (5.0%)	56.41 ± 16.82	$p = 0.52$

[a]Median (Interquartile range)—Mann Whitney *U* test.
[b]Mean ± standard deviation—Student's *t* test.
[c]Absolute number (percentage)—Chi squared test.

TABLE 4 Correlation operative time and number of procedures.

Surgeons RADN	Operative time	
Surgeon A (*N* = 21)	−0.209[a]	$p = 0.36$
Surgeon B (*N* = 19)	−0.179[a]	$p = 0.46$

[a]Pearson correlation.

were no differences in VAS-scores, neither on day 1 postoperative nor on day 3 postoperative when the effect of ropivacaine had worn off (half-life 1.8 h ± 0.7).[25]

Robotic surgery often faces scrutiny due to its higher costs compared to LDN. While length of hospital stay and complications are similar to LDN, RADN is more expensive.[26] Therefore, the additional value of robotic surgery to current procedures is debated. However, some studies have shown superior results favoring RADN. Achit et al.[26] demonstrated that RADN leads to better clinical outcomes compared to other procedures; so completing the learning curve recovery is better with RADN. This is corroborated by the meta-analysis by Khajeh et al. [27] Furthermore, patients who underwent RADN reported lower postoperative pain compared to LDN.[17] Also, robot-assisted surgery offers several advantages, including improved ergonomics for the surgeon,[28,29] fewer incisions, and an expansion of the skill set of the surgeon. It is expected that with increased use of robotic procedures, improvements made in technology, and the rising number of different competing platforms, costs will be reduced in the future, making robotic procedures more attractive compared to laparoscopic procedures.

This study has limitations due to its small dataset and retrospective nature. A randomized controlled trial would be necessary to conclusively determine significant differences between LDN and RADN. However, despite being retrospective and small-scale, there was no selection in this cohort as cases were randomly assigned electively on a weekly basis without taking account of LDN or RADN. If RADN was available, the case was assigned to RADN thereby limiting selection-bias.

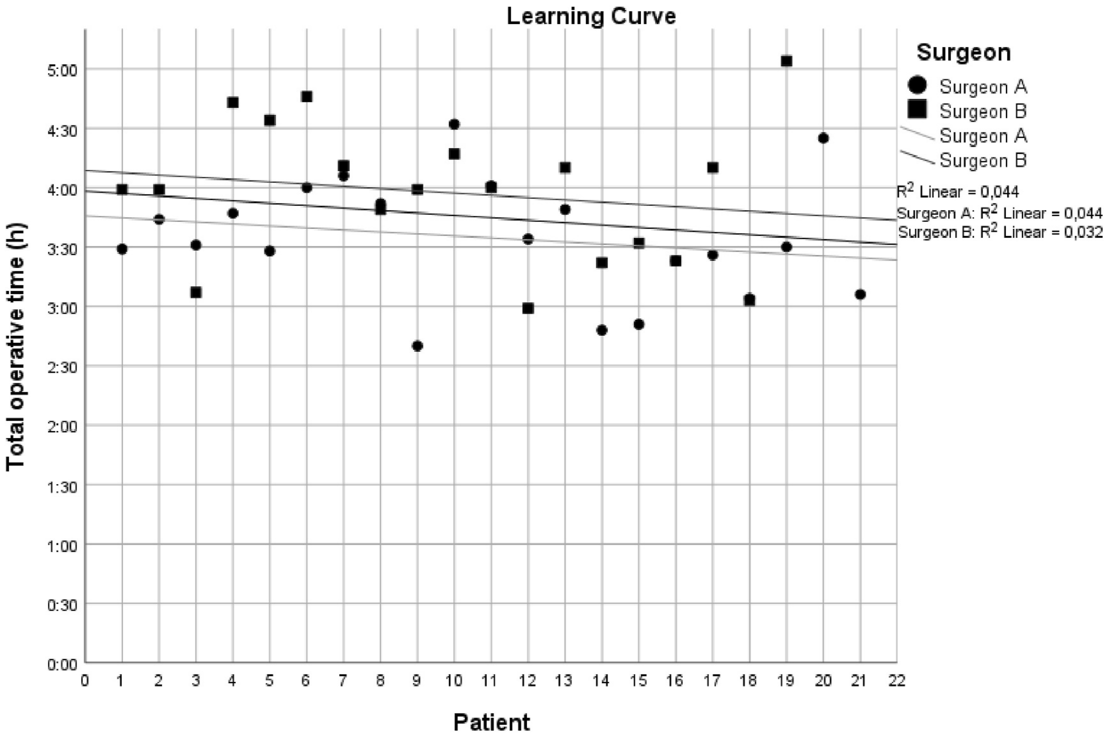

FIGURE 2 Learning curve robot-assisted donor nephrectomy.

Another potential limitation to consider was the variability in the surgeons performing the LDN. At the LUMC, an academic teaching hospital, surgical residents and fellows may perform parts of the LDN procedure, while two experienced surgeons performed all RADN procedures. This may have affected the laparoscopic results; but when only considering LDN cases performed by the same surgeons who conducted RADN, the results were consistent with those presented in Tables 2 and 3 (Appendix A).

5 | CONCLUSION

This retrospective case series demonstrated that RADN has been safely and effectively implemented in the LUMC by experienced laparoscopic surgeons, with outcomes non-inferior to the outcomes of laparoscopic donor nephrectomy.

AUTHOR CONTRIBUTIONS

Emma F. van de Geijn: Data curation, formal analysis, investigation, project administration, writing – original draft. **Shiromani Janki**: Formal analysis, investigation, supervision, writing – original draft. **Dorottya K. de Vries**: Resources, writing – review & editing. **Willemijn N. Nijboer**: Resources, writing – review & editing. **Ian P. J. Alwayn**: Resources, writing – review & editing. **Jeroen Nieuwenhuizen**: Resources, writing – review & editing. **Andrzej G. Baranski**: Resources, writing – review & editing. **Alexander F. M. Schaapherder**: Resources, writing – review & editing. **Aiko P. J. de Vries**: Resources, writing – review & editing. **Volkert A. L. Huurman**: Resources, supervision, validation, writing – review & editing. **Hwai-Ding Lam**: Conceptualization, resources, supervision, validation, writing – review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

ETHICS STATEMENT

This study was approved by the institutional review board (METC 2022-050) and informed consent was obtained from the participants.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

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REFERENCES

1. Minnee, R. C., and M. M. Idu. 2010. "Laparoscopic Donor Nephrectomy." *The Netherlands Journal of Medicine* 68(5): 199–206.
2. Ratner, L. E., L. J. Ciseck, R. G. Moore, F. G. Cigarroa, H. S. Kaufman, and L. R. Kavoussi. 1995. "Laparoscopic Live Donor Nephrectomy." *Transplantation* 60(9): 1047–9.
3. Koffron, A., C. Herman, O. Gross, M. Ferrario, D. Kaufman, M. Abecassis, J. Fryer, F. Stuart, and J. Leventhal. 2001. "Laparoscopic Donor Nephrectomy: Analysis of Donor and Recipient Outcomes." *Transplantation Proceedings* 33(1–2): 1111. https://doi.org/10.1016/s0041-1345(00)02437-4.
4. Ratner, L. E., L. R. Kavoussi, M. Sroka, J. Hiller, R. Weber, P. G. Schulam, and R. Montgomery. 1997. "Laparoscopic Assisted Live Donor Nephrectomy--a Comparison with the Open Approach." *Transplantation* 63(2): 229–33. https://doi.org/10.1097/00007890-199701270-00009.
5. Wilson, C. H., A. Sanni, D. A. Rix, and N. A. Soomro. 2011. "Laparoscopic versus Open Nephrectomy for Live Kidney Donors." *Cochrane Database of Systematic Reviews* 11: Cd006124. https://doi.org/10.1002/14651858.CD006124.pub2.
6. Horgan, S., D. Vanuno, and E. Benedetti. 2002. "Early Experience with Robotically Assisted Laparoscopic Donor Nephrectomy." *Surgical Laparoscopy Endoscopy & Percutaneous Techniques* 12(1): 64–70. https://doi.org/10.1097/00129689-200202000-00011.
7. Zeuschner, P., L. Hennig, R. Peters, M. Saar, J. Linxweiler, S. Siemer, A. Magheli, et al. 2020. "Robot-assisted versus Laparoscopic Donor Nephrectomy: A Comparison of 250 Cases." *Journal of Clinical Medicine* 9(6): 1610. https://doi.org/10.3390/jcm9061610.
8. Janki, S., K. W. J. Klop, S. M. Hagen, T. Terkivatan, M. G. H. Betjes, T. C. K. Tran, and J. N. M. Ijzermans. 2017. "Robotic Surgery Rapidly and Successfully Implemented in a High Volume Laparoscopic Center on Living Kidney Donation." *Int J Med Robot* 13(2). https://doi.org/10.1002/rcs.1743.
9. Wang, H., R. Chen, T. Li, and L. Peng. 2019. "Robot-assisted Laparoscopic vs Laparoscopic Donor Nephrectomy in Renal Transplantation: A Meta-Analysis." *Clinical Transplantation* 33(1): e13451. https://doi.org/10.1111/ctr.13451.
10. Geffner, S., Z. Klaassen, M. Tichauer, R. S. Chamberlain, and P. R. Paragi. 2011. "Robotic-assisted Laparoscopic Donor Nephrectomies: Early Experience and Review of the Literature." *Journal of Robot Surgery* 5(2): 115–20. https://doi.org/10.1007/s11701-011-0245-z.
11. Shin, T. Y., and Y. S. Lee. 2019. "Robot-assisted Laparoscopic Donor Nephrectomy: Surgical Feasibility and Technique." *Heliyon* 5(8): e02204. https://doi.org/10.1016/j.heliyon.2019.e02204.
12. Giacomoni, A., S. Di Sandro, A. Lauterio, I. Mangoni, P. Mihaylov, G. Concone, M. Tripepi, C. Poli, C. Cusumano, and L. De Carlis. 2013. "Initial Experience with Robot-Assisted Nephrectomy for Living-Donor Kidney Transplantation: Feasibility and Technical Notes." *Transplantation Proceedings* 45(7): 2627–31. https://doi.org/10.1016/j.transproceed.2013.07.038.
13. Yang, A., N. Barman, E. Chin, D. Herron, A. Arvelakis, D. LaPointe Rudow, S. S. Florman, and M. A. Palese. 2018. "Robotic-assisted vs. Laparoscopic Donor Nephrectomy: A Retrospective Comparison of Perioperative Course and Postoperative Outcome after 1 Year." *Journal of Robot Surgery* 12(2): 343–50. https://doi.org/10.1007/s11701-017-0741-x.
14. Garden, E. B., O. Al-Alao, S. Razdan, G. R. Mullen, S. Florman, and M. A. Palese. 2021. "Robotic single-port donor nephrectomy with the da vinci sp® surgical system." *Jsls* 25(4): e2021.00062. https://doi.org/10.4293/jsls.2021.00062.
15. Dumlu, E. G., İ. Kılınç, Ö. Parlak, M. Özsoy, B. Demirci, ¸S. Karakan, and M. Kilic. 2021. "Effect of Learning Curve on the Perioperative Course of Robotic-Assisted Laparoscopic Donor Nephrectomy Compared with Laparoscopic Donor Nephrectomy." *Revista da Associação Médica Brasileira* 67(7): 1033–7. https://doi.org/10.1590/1806-9282.20210526.
16. Takagi, K., H. J. A. N. Kimenai, T. Terkivatan, K. T. C. Tran, J. N. M. Ijzermans, and R. C. Minnee. 2021. "Learning Curves of Minimally Invasive Donor Nephrectomy in a High-Volume Center: A Cohort Study of 1895 Consecutive Living Donors." *International Journal of Surgery* 86: 7–12. https://doi.org/10.1016/j.ijsu.2020.12.011.
17. Habets, L. J. M., A. G. Baranski, K. Ramdhani, D. van der Helm, A. Haasnoot, A. P. J. de Vries, K. E. A. van der Bogt, et al. 2023. "The Non-muscle-splitting Mini-Incision Donor Nephrectomy Remains a Feasible Technique in the Laparoscopic Era of Living Kidney Donation." *Transplantology* 4(1): 1–11. https://doi.org/10.3390/transplantology4010001.
18. Leids Universitair Medisch Centrum. No date. *Onze expertise op het gebied van transplantatie [Internet]*. Leiden: Leids Universitair Medisch Centrum: [cited 2023 June 2]. Available from: https://www.lumc.nl/patientenzorg/specialistische-centra/lumc-transplantatie-centrum/lumc-transplantatie-centrum-voor-professionals/onze-expertise-op-het-gebied-van-transplantatie/.
19. Leids Universitair Medisch Centrum. No date. *Overleving (survival) van getransplanteerde nieren [Internet]*. Leiden: Leids Universitair Medisch Centrum: [cited 2023 June 2]. Available from: https://www.lumc.nl/patientenzorg/specialistische-centra/lumc-transplantatie-centrum/lumc-transplantatie-centrum-voor-professionals/overleving-survival-van-getransplanteerde-nieren/.
20. Clavien, P. A., J. Barkun, M. L. de Oliveira, J. N. Vauthey, D. Dindo, R. D. Schulick, E. de Santibañes, et al. 2009. "The Clavien-Dindo Classification of Surgical Complications: Five-Year Experience." *Annals of Surgery* 250(2): 187–96. https://doi.org/10.1097/SLA.0b013e3181b13ca2.
21. Slankamenac, K., R. Graf, J. Barkun, M. A. Puhan, and P.-Al. Clavien. 2013. "The Comprehensive Complication Index: A Novel Continuous Scale to Measure Surgical Morbidity." *Annals of Surgery* 258(1): 1–7. https://doi.org/10.1097/SLA.0b013e318296c732.
22. Bhattu, A. S., A. Ganpule, R. B. Sabnis, V. Murali, S. Mishra, and M. Desai. 2015. "Robot-assisted Laparoscopic Donor Nephrectomy vs Standard Laparoscopic Donor Nephrectomy: A Prospective Randomized Comparative Study." *Journal of Endourology* 29(12): 1334–40. https://doi.org/10.1089/end.2015.0213.
23. Özçelik, Ü., E. Eren, D. U. Urut, T. Talih, M. Tokaç, and A. Dinçkan. 2021. "Correlation between the Mayo Adhesive Probability Score and the Operative Time in Laparoscopic Donor Nephrectomy." *Transplantation Proceedings* 53(3): 793–8. https://doi.org/10.1016/j.transproceed.2020.10.013.
24. Takagi, K., H. J. A. N. Kimenai, T. Terkivatan, K. T. C. Tran, J. N. M. Ijzermans, and R. C. Minnee. 2021. "A Novel Difficulty Grading System for Laparoscopic Living Donor Nephrectomy."

Surgical Endoscopy 35(6): 2889–95. https://doi.org/10.1007/s00464-020-07727-w.
25. Kuthiala, G., and G. Chaudhary. 2011. “Ropivacaine: A Review of its Pharmacology and Clinical Use.” *Indian Journal of Anaesthesia* 55(2): 104–10. https://doi.org/10.4103/0019-5049.79875.
26. Achit, H., F. Guillemin, G. Karam, M. Ladrière, C. Baumann, L. Frimat, K. Hosseini, and J. Hubert. 2020. “Cost-effectiveness of Four Living-Donor Nephrectomy Techniques from a Hospital Perspective.” *Nephrology Dialysis Transplantation* 35(11): 2004–12. https://doi.org/10.1093/ndt/gfz143.
27. Khajeh, E., R. Nikbakhsh, A. Ramouz, A. Majlesara, M. Golriz, B. P. Müller-Stich, F. Nickel, C. Morath, M. Zeier, and A. Mehrabi. 2023. “Robot-assisted versus Laparoscopic Living Donor Nephrectomy: Superior Outcomes after Completion of the Learning Curve.” *Journal of Robot Surgery* 17(5): 2513–26. https://doi.org/10.1007/s11701-023-01681-0.
28. Elhage, O., D. Murphy, B. Challacombe, A. Shortland, and P. Dasgupta. 2007. “Ergonomics in Minimally Invasive Surgery.” *International Journal of Clinical Practice* 61(2): 186–8. https://doi.org/10.1111/j.1742-1241.2006.01243.x.
29. Hubert, N., M. Gilles, K. Desbrosses, Jp Meyer, J. Felblinger, and J. Hubert. 2013. “Ergonomic Assessment of the Surgeon's Physical Workload during Standard and Robotic Assisted Laparoscopic Procedures.” *Int J Med Robot* 9(2): 142–7. https://doi.org/10.1002/rcs.1489.

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SUPPORTING INFORMATION

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