Robotic Single-Port Donor Nephrectomy with the da Vinci SP® Surgical System

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ABSTRACT

Objectives: The da Vinci SP® Surgical System received U.S. Food and Drug Administration approval for urological procedures in 2018. Here, we describe the first experience performing single-port robot-assisted donor nephrectomy (RADN) using the da Vinci SP® surgical system, present 90-day clinical outcomes, and discuss tips for operative success.

Methods: Seven consecutive patients underwent single-port RADN at a single institution between September 1, 2020 and March 31, 2021. Surgery was performed through a single, 60 mm Pfannenstiel incision with a 12 mm periumbilical assistant port for suction and vascular stapling. Donor characteristics, operative details, 90-day donor clinical outcomes, and recipient renal function were retrospectively evaluated.

Results: Four female and three male patients successfully underwent single-port RADN without conversion to standard multiport or open approach. Six cases were left-sided. Estimated blood loss for each procedure was ≤ 50 mL. Mean operative time, warm ischemia time, and extraction time were 218.3 minutes (standard deviation [SD]: 16.3 minutes), 5 minutes 4 seconds (SD: 56 seconds), and 3 minutes 37 seconds (SD: 38 seconds). Mean pre-operative creatinine and estimated glomerular filtration rate were 0.79 mg/dL and 107.3 mL/min/1.73m^2, respectively. At six week's follow up, they were 1.22 mg/dL and 66.1 mL/min/1.73m^2. Average pain score at 48 hours post-operatively was 1.7/10. There were no Clavien-Dindo grade ≥ III complications within 90 days. All recipients experienced immediate and sustained return of renal function post-transplant.

Conclusion: Single-port RADN is a technically feasible and safe procedure with the da Vinci SP® system and can confer acceptable functional and cosmetic outcomes. Future studies are needed to define long-term outcomes and compare with previously established techniques for donor nephrectomy.

Key Words: Donor nephrectomy, Living donor, Robotic surgery, Single-port, Transplantation.

INTRODUCTION

Living donor nephrectomy (DN) is a unique surgery in that donors are healthy, altruistic individuals. Efforts towards maximizing donor safety and minimizing intra- and postoperative morbidity are of paramount importance to the medical community, many of which center on advancing minimally invasive surgical (MIS) options available.

Since it was first performed by Ratner and colleagues in 1995,[1] laparoscopic DN (LDN) has been the standard of care, resulting in increased donor recruitment, shorter hospitalizations, decreased pain, and superior cosmesis.[2–4] The da Vinci Surgical System (Intuitive Surgical, Mountain View, CA) and subsequent introduction of robot-assisted DN (RADN) in 2002[5] has offered surgeons a safe alternative to LDN with improved surgical vision and ergonomic relief.[6,7]

MIS techniques for DN progressed further in 2008[8] with the creation of a laparo-endoscopic single site (LESS) approach (commonly termed "single-port") that allows for instrument introduction and organ extraction through the same incision. While LESS-DN results in equivocal clinical outcomes with superior donor cosmesis and satisfaction, reports of significant technical challenges and steep

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learning curves with this approach have hindered its widespread adoption.[9,10] LaMattina et al. first successfully described a single-port RADN with the older-generation da Vinci Si® model in 2018.[11]

However, the development of the da Vinci SP® Surgical System – and its FDA clearance in 2018 for use in urologic procedures – offers a unique opportunity to explore the clinical feasibility of a single-port RADN with this newly available technology. The new "purpose-designed" single port (SP) platform uses a single, 25 mm multichannel trocar containing a high-definition, 3D robotic camera, and three instrument slots that deploy intracorporeally.

The SP platform has been successfully utilized for various urologic procedures with favorable clinical and cosmetic outcomes.[12–14] However, to our knowledge, there have been no reports describing use of the SP to perform DN. Here, we describe our initial clinical experience on single-port RADN using the da Vinci SP® Surgical System.

METHODS

Seven consecutive single-port RADN were performed between September 1, 2020 and March 31, 2021. All patients consented to undergo single-port RADN with the da Vinci SP® Surgical System with possible need for conversion to open surgery. All procedures were performed by the same team led by a fellowship-trained robotic surgeon (MAP).

Patients were placed in a flank position with arms extended superiorly slightly above the head. All pressure points were appropriately padded, and the patient was secured to the operative table in standard fashion. A 60 mm Pfannenstiel incision was used for abdominal entry, in which the GelPOINT® advanced access platform (Applied Medical, Rancho Santa Margarita, CA) was placed. The 25 mm SP multichannel trocar was then placed through the GelSeal Cap membrane and pneumoperitoneum was established at 12 – 15 mmHg (**Figure 1**). The three instrument slots were loaded with a Maryland bipolar forceps, Cadiere forceps, and monopolar scissor (Intuitive Surgical, Mountain View, CA), with fenestrated bipolar forceps available for interchange when necessary intraoperatively. A separate, 12 mm paraumbilical incision was made for assistant port placement and introduction of a suction device or Endo GIA™ Universal Staplers (Medtronic, Dublin, Ireland) (**Figure 1**).

For these procedures, we used our previously published 12-step guide to single-port RADN.[15] The descending colon and spleen were dissected and, along with the pancreas, moved medially to expose the renal hilum. The gonadal and adrenal veins were dissected and divided, after which the renal vessels were dissected proximally to their origins at the aorta and inferior vena cava for maximal allograft length. The upper pole of the kidney and the adrenal gland were dissected superiorly, followed by the lower pole and ureter inferiorly. The posterolateral renal

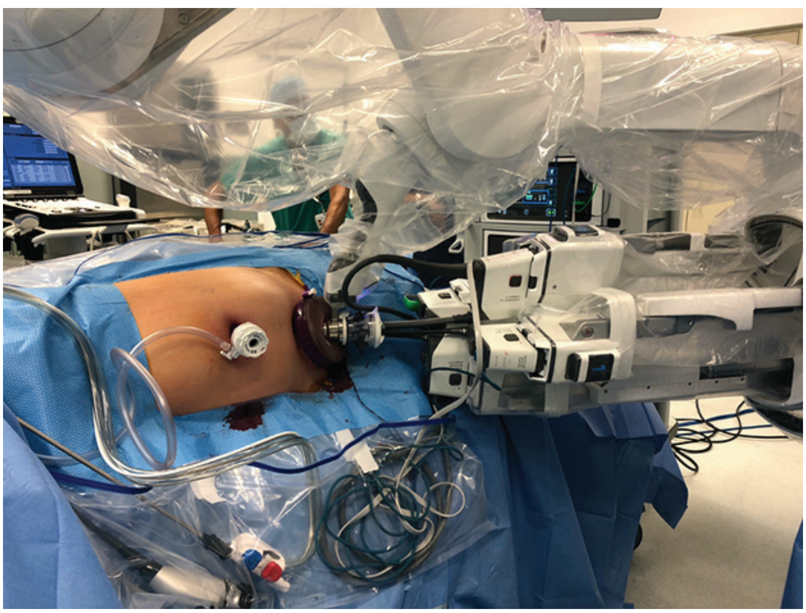

Figure 1. Port placement and instrument positioning for single-port robot-assisted donor nephrectomy using the da vinci single port® surgical system.

attachments were then dissected for optimal hilar visualization. Endo GIA™ staples were used for ureteral division at the level of the iliac vessels, at which point a free EndoCatch™ Specimen Retrieval Pouch (Medtronic, Dublin, Ireland) was introduced via the assistant port. The kidney and ureter were placed in the bag and secured with Hem-o-Lok® clips leaving the hilum exposed.

Once the recipient team was ready for organ extraction, the renal vessels were stapled and divided with 30 mm vascular Endo GIA™ staples. At this point, the multichannel trocar and GelPOINT® were removed and the robot was undocked and removed from the operative field. The skin incision and underlying fascia were extended to accommodate extraction of the organ. After extraction via the original Pfannenstiel incision, the robot was redocked and hemostasis was achieved. Fascial closure was performed using running 2-0 PDS with subcuticular closure by 0-Vicryl and 4-0 Monocryl for skin.

After obtaining institutional review board approval, donor demographic, perioperative, and clinical data was retrospectively collected. Demographic data included patient age and sex. Perioperative data included procedure laterality, entry point, estimated blood loss (EBL), operative time, warm ischemia time (WIT), extraction time, and length of stay. Clinical data included American Society of Anesthesiologists score, body mass index, serum creatinine measured pre-operatively, on postoperative day (POD) 1, discharge, and at follow-up visits, and Clavien-Dindo grade ≥ II complications within 90 days postoperatively. Estimated glomerular filtration rate (eGFR) was calculated from serum creatinine levels using the Chronic Kidney Disease Epidemiology Collaboration equation.[16] Recipient pre- and postoperative serum creatinine values were retrospectively collected. Average donor pain score (self-reported on a scale of 0 – 10) was calculated at regular postoperative intervals as reported in nursing notes for each shift. Finally, postoperative analgesic use was recorded based on the donor's medication administration record, with doses converted to a standardized oral morphine milligram equivalent (MME).

RESULTS

All patients – four females and three males – successfully underwent single-port RADN via Pfannenstiel incision (**Table 1**). Six cases were left-sided, and one was right-sided. Mean patient age was 40.3 years (standard deviation [SD] 15.8). Mean total operative time was 218.3 minutes (SD 16.3), while mean WIT was 5 minutes 4 seconds (SD 56 seconds). All cases had an EBL ≤ 50 cc. No cases required conversion.

All hospitalizations were uncomplicated, with a mean hospitalization of 2.1 days (SD: 0.4). Of note, patients 2 and 5 were eligible for discharge on POD 1, but both requested to extend their admission an extra day for personal reasons. At two-week's follow-up, all wounds were well-healed with excellent cosmetic results (**Figure 2**).

Mean baseline donor serum creatinine and eGFR were 0.79 mg/dL (SD 0.17 mg/dL) and 107.3 mL/min/1.73 m^2 (SD 17.0 mL/min/1.73 m^2), respectively. On average, donors saw a 63.3% increase in serum creatinine and a 41.7% reduction in eGFR at the time of discharge. However, at six month's follow-up, average creatinine and eGFR were 1.15 mg/dL and 68.4 mL/min/1.73 m^2. Further, all recipients saw return of renal function post-transplant, with adequate renal functionality maintained up to 62 – 351 days postoperatively (**Figure 3**).

Patients reported greatest pain at 4 – 8 hours postoperatively, rating their pain at 3.8/10 on average; these scores dropped to 1.7/10 by 36 – 48 hours postoperatively. The average MME requirement between 0 – 24 and 24 – 48 hours postoperatively were 41.4 mg (SD 33.7 mg) and 16.8 mg (SD 16.5 mg), respectively.

No donor suffered a Clavien-Dindo grade ≥ III complication. Patient 5 was diagnosed with epididymoorchitis on POD 6, while patient 6 experienced a superficial incisional infection on POD 6; both were treated successfully with empiric antibiotic therapy.

DISCUSSION

Here, we demonstrate single-port RADN can be safely and effectively performed using the da Vinci SP® Surgical System. To our knowledge, this is the first ever series of single-port RADN using this system, highlighting a significant step forward in optimizing the MIS options available for eligible kidney donors.

Following Kaouk et al.'s initial publication describing the feasibility of robot-assisted partial nephrectomy with the da Vinci SP® Surgical System,[13] several groups have offered subsequent, larger series indicating clinical and cosmetic successes.[14,17] Other studies have reported successes performing SP robotic pyeloplasty, kidney transplantation, and autotransplantation.[18,19] Takeaways from these series have highlighted advantages with the SP ranging from technical aspects like greater ease with intracorporeal instrumentation and superior camera control, to

Table 1.
Demographic, Clinical, and Perioperative Data of Patients Undergoing Single-Port Robot-Assisted Donor Nephrectomy Using the da Vinci Single Port® Surgical System at a Single Academic Institution Between September 1, 2020 – March 31, 2021

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Mean (SD)
Age (years)	42	57	40	64	21	26	32	40.3 (15.8)
Sex	Female	Female	Male	Female	Male	Female	Male	
ASA	1	1	1	2	1	2	1	
BMI (kg/m^2)	24.00	23.42	27.53	22.13	26.79	37.32	23.56	26.79 (5.57)
Laterality	Left	Left	Left	Right	Left	Left	Left	
Abdominal entry point	Pfannenstiel	Pfannenstiel	Pfannenstiel	Pfannenstiel	Pfannenstiel	Pfannenstiel	Pfannenstiel	
Estimated blood loss (mL)	50	25	25	25	25	50	50	35.7 (13.4)
Operative time (minutes)	237	220	206	237	219	218	191	218.3 (16.3)
Warm ischemia time (minutes)	6.52	4.42	3.83	5.18	4.42	5.95	5.20	5.07 (0.94)
Extraction time (minutes)	4.28	3.25	2.78	4.08	3.22	4.43	3.20	3.61 (0.64)
Length of stay (days)	2	2	2	3	2	2	2	2.1 (0.4)
Creatinine (mg/dL)								
Preoperative	0.67	0.69	0.97	0.78	1.00	0.55	0.89	0.79 (0.17)
Postoperative day 1	1.13	1.19	1.49	1.01	1.44	0.87	1.20	1.19 (0.24)
Discharge	1.09	1.26	1.76	1.09	1.45	0.91	1.49	1.29 (0.29)
Two week follow-up	1.00	1.07	1.44	1.16	1.38	0.84	Not assessed	1.15 (0.23)
Six week follow-up	1.00	1.22	1.44	1.15	1.43	0.93	1.37	1.22 (0.21)
Six month follow-up	0.90	0.97	1.37	1.13	1.39	Not assessed	Not assessed	1.15 (0.22)
eGFR (mL/min/1.73 m^2)*								
Pre-operative	109	97	97	81	124	130	113	107.3 (17.0)
Postoperative day 1	60	51	58	59	80	92	80	68.6 (15.3)
Discharge	63	47	47	54	79	87	61	62.6 (15.4)
Two week follow-up	70	58	60	50	84	96	Not assessed	69.7 (17.4)
Six week follow-up	70	49	60	50	81	85	68	66.1 (14.1)
Six month follow-up	79	65	64	51	83	Not assessed	Not assessed	68.4 (12.8)
Average postoperative pain score								
0 – 4 hours	0	0	3.8	5.8	6.2	4.5	0	2.9 (2.8)
4 – 8 hours	7	2.5	Not assessed	2	6.3	1	4.25	3.8 (2.4)
8 – 12 hours	5	0	4.3	0	7	6	0	3.2 (3.1)
12 – 24 hours	4	1.25	4	4	5.8	5	0	3.4 (2.1)

Table 1. Continued

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Mean (SD)
24 – 36 hours	2.7	4.3	2	3.1	5.3	5.25	0	3.2 (1.9)
36 – 48 hours	0	5	0	2.5	0	4.5	0	1.7 (2.3)
> 48 hours	N/A	N/A	N/A	5.7	0	N/A	N/A	2.9 (4.0)
Postoperative oral morphine milligram equivalent								
0 – 24 hours	0	37.5	67.5	22.5	90	64.8	7.5	41.4 (33.7)
24 – 48 hours	7.5	45	0	20	15	30	0	16.8 (16.5)
48 – 72 hours	N/A	N/A	N/A	0	0	N/A	N/A	0 (0)
Complications								
30 Days	None	None	None	None	Clavien-Dindo II	Clavien-Dindo II	None	
90 Days	None	None	None	None	None	None	None	

*Calculated using the CKD-EPI Creatinine equation for estimated glomerular filtration rate.

Figure 2. Postoperative cosmetic results for patient 5 who underwent single-port robot-assisted donor nephrectomy using the da vinci single port® surgical system.

clinical outcomes like low pain scores and potentially decreased narcotic prescriptions. The SP system has also been successfully utilized to perform radical cystectomy[20] and prostatectomy,[21] offering a broader look at how this technology can be leveraged in urologic surgery.

LaMattina et al.'s three-patient series offered the first glimpse at single-port RADN, reporting an average operative time of 262 minutes, average blood loss of 77 mL, and uncomplicated recoveries for all patients.[11] Though originally approved to perform 20 procedures, the authors terminated their investigation prematurely – as their team exclusively performs LESS-DN with excellent outcomes, they felt the utility of incorporating the robotic platform was limited due to procedural inefficiencies and complexities and a lack of instrumentation and energy devices. Those, coupled with increased costs, led them to conclude the robotic single-port platform did not yet confer a clear benefit.

Still, given the technical demands with LESS-DN combined with growing interest in single-site robotic surgery,[22] we believe the present report offers value to the surgical community at large. Additionally, there are several differences between these two series. Their procedures – performed with the older generation da Vinci Si® model – were not purely robotic; instead, the team began each surgery following their institution's standard LESS technique for colonic dissection and mobilization, at which point the robot was docked and introduced. The da Vinci Si® was then used for gonadal vein isolation and ureteral and hilar dissection. Once these steps were

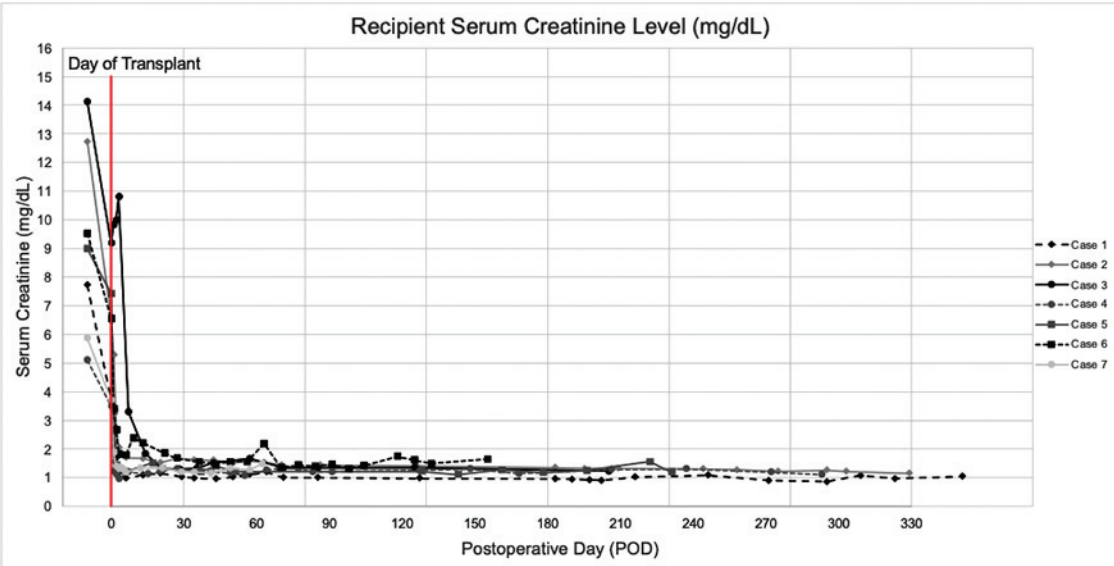

Figure 3. Recipient serum creatinine levels before and after renal transplantation, with organs extracted from the single-port robot-assisted donor nephrectomy using the da vinci single port® surgical system.

performed, the robot was undocked and the final vascular dissection and stapling, followed by renal extraction were performed laparoscopically. In contrast, our procedures used the new, "purpose-built" SP system with accompanying instruments in a completely robotic procedure. Furthermore, aside from renal vascular stapling performed laparoscopically via the periumbilical assistant port, our entire surgery was performed robotically. Additionally, unlike our cohort, their study excluded right-sided donors.

The results presented in this report are comparable to previous studies of LDN, LESS-DN, and multiport RADN. Our average operative time was 218.3 minutes, whereas meta-analyses of LDN, LESS-DN, and multiport RADN have found operative times ranging between 117 –239 minutes,[23] 142 – 269 minutes,[23] and 139 – 306 minutes,[24] respectively. Meanwhile, our mean WIT of 5.1 minutes falls within the range of previous studies of LDN (2.6 – 5.1 minutes),[23,25] LESS-DN (2.8 – 7.15 minutes),[23,25] and multiport RADN (1.5 – 5.8 minutes).[24] While the operative times and WITs fall on the longer end, we are encouraged by a trend demonstrating improvements in these metrics with subsequent cases, which we feel will continue with further experience. Finally, all recipients had immediate and sustained return of renal function posttransplant, preliminarily highlighting this procedure does not hinder recipient recovery, though further longitudinal research is necessary to validate these claims.

Prior meta-analyses comparing LESS to laparoscopic renal surgery have found single-site surgery conferred decreased postoperative analgesic requirements.[23,26] The average inpatient MME requirement in this series was approximately 58 mg, which fell within the range of analgesic requirements reported in both meta-analyses. Additionally, we were satisfied that patients reported low levels of pain during their hospitalizations and at discharge. However, whether this new surgical approach reduces postoperative pain compared to alternative techniques can only be answered in the context of a prospective, randomized trial.

As with any new procedure, there will be a learning curve to optimize operative technique. However, in these initial cases our team has gleaned several tips we will incorporate into future surgeries. Single-port surgery can limit the size of the operative field and restrict instrument reach and mobility. To overcome these difficulties, we found placing patients in the standard flank position with both arms extended superiorly slightly above the head maximizes space for robotic docking without instrument clashing (**Figure 1**). In this position, the trocar base must be lowered so the surgical instruments can be angled superiorly for optimal renal access, though it is important to avoid contaminating the bottom of the robot.

Though paramedian and paraumbilical incisions are theoretically feasible entry points, we believe a Pfannenstiel incision is the best approach, guided by previous studies which have shown this incision is cosmetically favorable among kidney donors[27] and associated with decreased pain and morbidity after nephrectomy.[28] Regarding optimal incision length, the surgeon must ensure the fascial opening is vertically wide enough to not only allow for introduction of the 25 mm trocar, but to facilitate renal delivery during extraction. We have found 60 mm Pfannenstiel and 60 mm midline vertical fascial incisions, combined with hand dilation of the openings, are sufficiently large for this purpose. We also recommend use of a GelPOINT® access port and Alexis wound protector throughout the procedure, as the incision is relatively large and trocar movement intraoperatively increases the risk of air leak and loss of pneumoperitoneum. The trocar should be placed through the GelPOINT® before being connected to the wound protector.

Another difficulty of single-port surgery relates to the lack of certain robotic instruments compatible with the da Vinci SP® Surgical System platform. As the da Vinci SP® Surgical System platform does not offer an accompanying robotically controlled vascular stapler similar to the existing system, we used a 12 mm umbilical assistant port to pass the laparoscopic stapler in a safe and controlled manner. For right-sided cases, a liver retractor can be introduced via the assistant port as well. Notably, following Dobbs and colleagues' first purely single-port radical nephrectomy, a patient experienced postoperative hemorrhage secondary to inadequate vascular control of the renal artery, prompting them to amend their technique to incorporate a 12 mm assistant port.[29] We hope to attempt a purely single-port procedure in future cases, though this transition will be made gradually following upgrades to SP technology that allow for robotic stapling. We have attempted to introduce the stapler through the Pfannenstiel incision via an 8 mm trocar placed in the GelPOINT®; however, instrument clashing with the robot during hilar dissection made this approach technically challenging. Furthermore, performing a purely SP procedure will not eliminate the need for a bedside assistant, and though an 8 mm trocar passed through the GelPOINT® is not suitable for dissection, it can be placed quickly and used effectively in case there is a major bleed intraoperatively.

During renal extraction, the patient should be fully relaxed to allow for easier extraction throughout the incision, and gas should be off to prevent bowel protrusion out of the incision. Additionally, we recommend the specimen bag be held with a laparoscopic Davis & Geck grasper through the robotic port, not the assistant port, as this allows for superior maneuverability of the kidney.

In these cases, we encountered initial difficulties with the amount of working space and instrument length when attempting to reach the anatomically superior left upper pole. To maximize internal working space, the Alexis should be wound as close to the skin as possible before being connected to the GelPOINT®; the SP port should be pushed in as far as possible; and the GelPOINT® can be burped outward to air-dock the SP trocar. Lenfant et al. have found the floating docking technique can increase surgical working space, particularly for radical prostatectomy.[30] However, for DN via Pfannenstiel incision, we found this approach decreases robotic reach and hinders splenic dissection.

Though the new modalities offered by the da Vinci SP® Surgical System platform have been detailed elsewhere,[12,29] there are several we wish to highlight here. The navigator's live tracking and display of relative instrument and camera positioning is helpful in monitoring instruments off-screen. This display also facilitates quick camera repositioning into the new "Cobra Mode" – achieved when the camera is midline and flexed upwards 30 degrees – offering an overhead view of the surgical field; this view was particularly useful for obtaining better hilar visualization.

This report is not without limitations. Its retrospective design potentially exposes our findings to selection bias, its sample size of seven patients limits its generalizability, and the lack of long-term follow-up limits our understanding of the clinical advantages or disadvantages associated with this new technique. Future, prospective studies to explore the long-term donor outcomes, as well as comparative analyses with extant surgical techniques, are necessary to validate the feasibility of single-port RADN. Still, we believe this series offers important insight into the utility of the da Vinci SP® Surgical System for RADN, and these preliminary results indicate the SP can confer acceptable functional and cosmetic outcomes.

CONCLUSION

Here, we report the safety and feasibility of single-port RADN using the da Vinci SP® Surgical System. Additionally, we offer our surgical technique and tips, hopefully serving as a guide for other surgical teams exploring future incorporation of the SP surgical system. All cases were performed without conversion, and postoperative courses were largely uncomplicated with well-healed, cosmetically satisfactory scars at follow-up. Future randomized studies are necessary to better define long-term clinical outcomes and to compare single-port RADN with previously established DN techniques.

References:

1. Ratner LE, Ciseck LJ, Moore RG, Cigarroa FG, Kaufman HS, Kavoussi LR. Laparoscopic live donor nephrectomy. *Transplantation*. 1995;60(9):1047–1049.

2. Schweitzer EJ, Wilson J, Jacobs S, et al. Increased rates of donation with laparoscopic donor nephrectomy. *Ann Surg*. 2000;232(3):392–400.

3. Yuan H, Liu L, Zheng S, et al. The safety and efficacy of laparoscopic donor nephrectomy for renal transplantation: an updated meta-analysis. *Transplantation Proceedings*. 2013;45 (1):65–76.

4. Wilson CH, Sanni A, Rix DA, Soomro NA. Laparoscopic versus open nephrectomy for live kidney donors. *Cochrane Database Syst Rev*. 2011;(11):CD006124.

5. Horgan S, Vanuno D, Sileri P, Cicalese L, Benedetti E. Robotic-assisted laparoscopic donor nephrectomy for kidney transplantation. *Transplantation*. 2002;73(9):1474–1479.

6. Shin TY, Lee YS. Robot-assisted laparoscopic donor nephrectomy: surgical feasibility and technique. *Heliyon*. 2019;5 (8):e02204.

7. Marçon B, Ngueyon Sime W, Guillemin F, et al. An ergonomic assessment of four different donor nephrectomy approaches for the surgeons and their assistants. *Res Rep Urol*. 2019;11:261–268.

8. Gill IS, Canes D, Aron M, et al. Single port transumbilical (E-NOTES) donor nephrectomy. *J Urol*. 2008;180(2):637–641; discussion 41.

9. Barth RN, Phelan MW, Goldschen L, et al. Single-port donor nephrectomy provides improved patient satisfaction and equivalent outcomes. *Ann Surg*. 2013;257(3):527–533.

10. Afaneh C, Aull MJ, Gimenez E, et al. Comparison of laparoendoscopic single-site donor nephrectomy and conventional laparoscopic donor nephrectomy: donor and recipient outcomes. *Urology*. 2011;78(6):1332–1337.

11. LaMattina JC, Alvarez-Casas J, Lu I, et al. Robotic-assisted single-port donor nephrectomy using the da Vinci single-site platform. *Journal of Surgical Research*. 2018;222:34–38.

12. Kaouk J, Aminsharifi A, Sawczyn G, et al. Single-port robotic urological surgery using purpose-built single-port surgical system: single-institutional experience with the first 100 cases. *Urology*. 2020;140:77–84.

13. Kaouk J, Garisto J, Eltemamy M, Bertolo R. Pure single-site robot-assisted partial nephrectomy using the SP surgical system: initial clinical experience. *Urology*. 2019;124:282–285.

14. Shukla D, Small A, Mehrazin R, Palese M. Single-port robotic-assisted partial nephrectomy: initial clinical experience and lessons learned for successful outcomes. *J Robot Surg*. 2021; 15(2):293–298.

15. Garden EB, Al-Alao O, Razdan S, Florman SS, Ames SA, Palese MA. Robot-assisted single-port donor nephrectomy using the da Vinci Single-Port (SP) Surgical Platform. *Urology Video Journal*. 2021;10:100086.

16. Levey AS, Stevens LA. Estimating GFR using the CKD Epidemiology Collaboration (CKD-EPI) creatinine equation: more accurate GFR estimates, lower CKD prevalence estimates, and better risk predictions. *Am J Kidney Dis*. 2010;55(4):622–627.

17. Fang AM, Saidian A, Magi-Galluzzi C, Nix JW, Rais-Bahrami S. Single-port robotic partial and radical nephrectomies for renal cortical tumors: initial clinical experience. *J Robot Surg*. 2020;14 (5):773–780.

18. Kaouk J, Eltemamy M, Aminsharifi A, et al. Initial experience with single-port robotic-assisted kidney transplantation and autotransplantation. *Eur Urol*. 2021;80(3):366–373.

19. Lenfant L, Wilson CA, Sawczyn G, Aminsharifi A, Kim S, Kaouk J. Single-port robot-assisted dismembered pyeloplasty with mini-pfannenstiel or peri-umbilical access: initial experience in a single center. *Urology*. 2020;143:147–152.

20. Zhang M, Thomas D, Salama G, Ahmed M. Single port robotic radical cystectomy with intracorporeal urinary diversion: a case series and review. *Transl Androl Urol*. 2020;9(2):925–930.

21. Kaouk J, Bertolo R, Eltemamy M, Garisto J. Single-port robot-assisted radical prostatectomy: first clinical experience using the SP Surgical System. *Urology*. 2019;124:309.

22. Autorino R, Kaouk JH, Stolzenburg J-U, et al. Current status and future directions of robotic single-site surgery: a systematic review. *Eur Urol*. 2013;63(2):266–280.

23. Autorino R, Brandao LF, Sankari B, et al. Laparoendoscopic single-site (LESS) vs laparoscopic living-donor nephrectomy: a systematic review and meta-analysis. *BJU Int*. 2015;115(2):206–215.

24. Creta M, Calogero A, Sagnelli C, et al. Donor and recipient outcomes following robotic-assisted laparoscopic living donor nephrectomy: a systematic review. *Biomed Res Int*. 2019; 2019:1729138.

25. Gupta A, Ahmed K, Kynaston HG, Dasgupta P, Chlosta PL, Aboumarzouk OM. Laparoendoscopic single-site donor nephrectomy (LESS-DN) versus standard laparoscopic donor nephrectomy. *Cochrane Database Syst Rev*. 2016;2016 (5):CD010850.

26. Fan X, Lin T, Xu K, et al. Laparoendoscopic single-site nephrectomy compared with conventional laparoscopic nephrectomy: a

systematic review and meta-analysis of comparative studies. *European Urology.* 2012;62(4):601–612.

27. Saito M, Tsuchiya N, Maita S, et al. What is the most preferred wound site for laparoscopic donor nephrectomy?: a questionnaire assessment. *J Laparoendosc Adv Surg Tech A.* 2011;21(6):511–515.

28. Binsaleh S, Madbouly K, Matsumoto ED, Kapoor A. A prospective randomized study of pfannenstiel versus expanded port site incision for intact specimen extraction in laparoscopic radical nephrectomy. *Journal of Endourology.* 2015;29(8):913–918.

29. Dobbs RW, Halgrimson WR, Talamini S, Vigneswaran HT, Wilson JO, Crivellaro S. Single-port robotic surgery: the next generation of minimally invasive urology. *World J Urol.* 2020;38(4):897–905.

30. Lenfant L, Kim S, Aminsharifi A, Sawczyn G, Kaouk J. Floating docking technique: a simple modification to improve the working space of the instruments during single-port robotic surgery. *World J Urol.* 2021;39(4):1299–1305.