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Initial Experience with Robot-Assisted Minimally Invasive Nephroureterectomy

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ABSTRACT

***Purpose*: Various techniques have been described for laparoscopic nephroureterectomy. We reviewed our initial experience of laparoscopic nephroureterectomy with robot-assisted extravesical excision of the distal ureter and bladder cuff.**

***Materials and Methods*: Nine consecutive patients aged 43 to 83 years underwent laparoscopic nephroureterectomy for transitional cell carcinoma (TCC) between August 2005 and March 2007. The first five patients were repositioned after laparoscopic nephrectomy from flank to lithotomy position to dock the robot for excision of the distal ureter and bladder cuff by a single surgeon. In contrast, the last four patients remained in flank position throughout the entire procedure, with the robot docked in flank position following laparoscopic nephrectomy. A two-layer closure re-approximated the cystotomy and a urethral catheter was left in place for a mean of 5 days.**

***Results*: Eight men and one woman with a mean age of 64.2 years and mean body mass index (BMI) of 28.4 kg/m^2 underwent flexible cystoscopy and laparoscopic nephroureterectomy for five right-sided and four left-sided tumors. Mean operative time was 303 minutes (range 210–430 minutes), estimated blood loss was 211 mL (range 50–700 mL), and mean length of hospital stay was 2.3 days. Pathologic staging revealed T_3 for five (55.6%), T_a for two (22.2%), carcinoma *in situ* (CIS) for two (22.2%) patients, and high-grade disease for seven (77.8%) patients. With a mean follow-up of 16.2 months (range 4.3–24.3 months), three patients with a history of bladder cancer have experienced recurrence in the bladder, and one of the three has also developed metastatic disease.**

***Conclusions*: Laparoscopic nephroureterectomy with robot-assisted extravesical excision of the distal ureter and bladder cuff appears to be a feasible alternative for patients with TCC of the upper urinary tract.**

INTRODUCTION

THE ADVENT OF MINIMALLY-INVASIVE RENAL SURGERY has led to the use of different techniques and approaches with the common goal of replicating the gold standard open procedure. Laparoscopic nephroureterectomy was first reported in 1991,[1] and many subsequent variations have been described. Most recently, different techniques have arisen regarding management of the bladder cuff and distal ureter, including open excision, a transvesical and laparoscopic detachment and ligation technique, laparoscopic stapling of the distal ureter and bladder cuff, the "pluck" technique, and ureteral intussusception.[2] We present our initial experience using robot-assisted excision of the distal ureter and bladder cuff and closure of the cystotomy.

MATERIALS AND METHODS

Between August 2005 and March 2007, nine consecutive patients (eight men and one woman) underwent flexible cystoscopy laparoscopic nephroureterectomy with robot-assisted excision of the distal ureter and bladder cuff (Table 1). All patients were referred for operative management of upper tract transitional cell carcinoma (TCC) and no patients were excluded. Data were collected prospectively. Preoperative work-

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Table 1. Patient Demographic Data

Patient	*Age (years)*	*Lesion side*	*BMI*	*Hematuria*	*History of bladder cancer*	*Diagnosed*
1	43	Right	33.1	Gross	No	Ureteroscopically
2	82	Right	21.5	Gross	Yes	Retrograde pyelogram selective cytology
3	76	Right	27	Microscopic	No	CT urogram
4	56	Left	35.2	Gross	Yes	MR urogram
5	67	Left	24.7	Microscopic	Yes	Retrograde pyelogram selective cytology
6	83	Left	22.15	Gross	No	Ureteroscopically
7	82	Left	28.1	Gross	No	Previous ureterectomy
8	54	Right	25.3	Microscopic	No	Ureteroscopically
9	55	Right	38.6	Gross	No	Ureteroscopically

up included upper tract imaging or ureteroscopy, and urine cytology. Five patients had right-sided tumors, and four patients had left-sided tumors. Moreover, six patients presented with gross hematuria, while the other three had microscopic hematuria. All patients had findings suspicious for TCC on upper tract imaging. In addition, all patients underwent flexible cystoscopy minimally-invasive nephroureterectomy. Operative time included time from initial incision to skin closure of all incisions. All laboratory calculations utilized preoperative and recovery room blood draws.

The first patient in the series underwent retroperitoneoscopic right radical nephrectomy due to a history of open cholecystectomy and appendectomy, while the other eight patients underwent transperitoneal laparoscopic radical nephrectomy. In all instances, robot-assisted laparoscopic dissection of the distal ureter and the bladder cuff followed laparoscopic radical nephrectomy.

For the first patient, retroperitoneoscopic radical nephrectomy was performed as described by Gill and associates.[3] The ureter was dissected as distally as possible, just proximal to the common iliac vessels. After dividing the hilar vessels with the endovascular stapler and freeing the kidney and Gerota's fascia from surrounding attachments, the specimen was placed in a 15-mm specimen bag with the ureter exiting the cinched bag opening. In addition, a clip was placed on the mid-ureter to prevent potential seeding from the upper tract to the bladder. A peritoneal window was created and the specimen was delivered from the retroperitoneum to the abdominal cavity. Retroperitoneal trocar sites were then closed with the exception of the 12-mm port placed in the anterior axillary line, which was replaced with a 16F Foley catheter with the balloon inflated. The patient was then repositioned from the full flank position to lithotomy position with steep Trendelenburg, and the 16F Foley was then switched out for a 12-mm Autosuture® port (Tyco International, Princeton, NJ), which was carefully guided into the abdomen without resistance, and pneumoperitoneum was established. This port then served as the assistant port for suction, irrigation, passing, and cutting sutures. A supraumbilical 12-mm port was then placed to accommodate the camera, and the 8-mm ports were placed at the lateral rectus border in a horizontal plane 2 to 4 cm below the umbilicus. The robot was then docked, and the ureter was dissected distally. Upon reaching the bladder detrusor fibers, the bladder was filled with 60 mL and the catheter was plugged. Care was taken to achieve a 1 cm margin of bladder cuff around the ureteral stump, and the specimen bag was opened slightly to place the distal ureter and bladder cuff with the kidney. The bladder was then closed in two layers with 3-0 Vicryl running sutures, and the bladder was filled with 120 mL to assess for leakage. Drains were not placed after confirming watertight closure by filling the bladder with irrigation. Finally, the supraumbilical camera port site was extended in the midline to remove the specimen.

For the completely transperitoneal approach, the bladder cuff and distal ureteral dissection were performed as described above. In the first stage of the procedure, transperitoneal laparoscopic radical nephrectomy was performed with the port sites placed as shown in Figure 1A. The first four patients who underwent the transperitoneal approach were repositioned from the flank to a low lithotomy position to allow docking of the robot between the legs. In contrast to the retroperitoneoscopic approach, two ports were shared between the first and second stages of the procedure: (1) the lateral 12-mm port at the anterior axillary line facilitated lateral traction during renal hilar dissection during the first stage, and was used by the bedside assistant during the second stage to provide exposure, suction, and passage of suture for the cystotomy closure; (2) the most caudad 12-mm port along the rectus margin was switched to an 8-mm robotic trocar for the second stage. Two new trocar sites were placed (Fig. 1B) for the robot-assisted distal ureterectomy and excision of bladder cuff: (1) a supraumbilical midline 12-mm trocar served as the robotic camera port; (2) an 8-mm robotic trocar contralateral to the side of nephroureterectomy was placed 2 to 4 cm inferior to the umbilicus at the lateral rectus margin. Finally, the camera port site was extended to retrieve the laparoscopic bag containing the specimen, and Figure 2 demonstrates the postoperative appearance of the wound sites.

A total of eight patients underwent transperitoneal laparoscopic nephrectoureterectomy. For three patients in the series, we modified our approach and kept the patients in flank position throughout the procedure, docking the robot in at a 30° angle to the foot of the table for the distal ureterectomy, as demonstrated in Figure 3. Several technical features minimized the

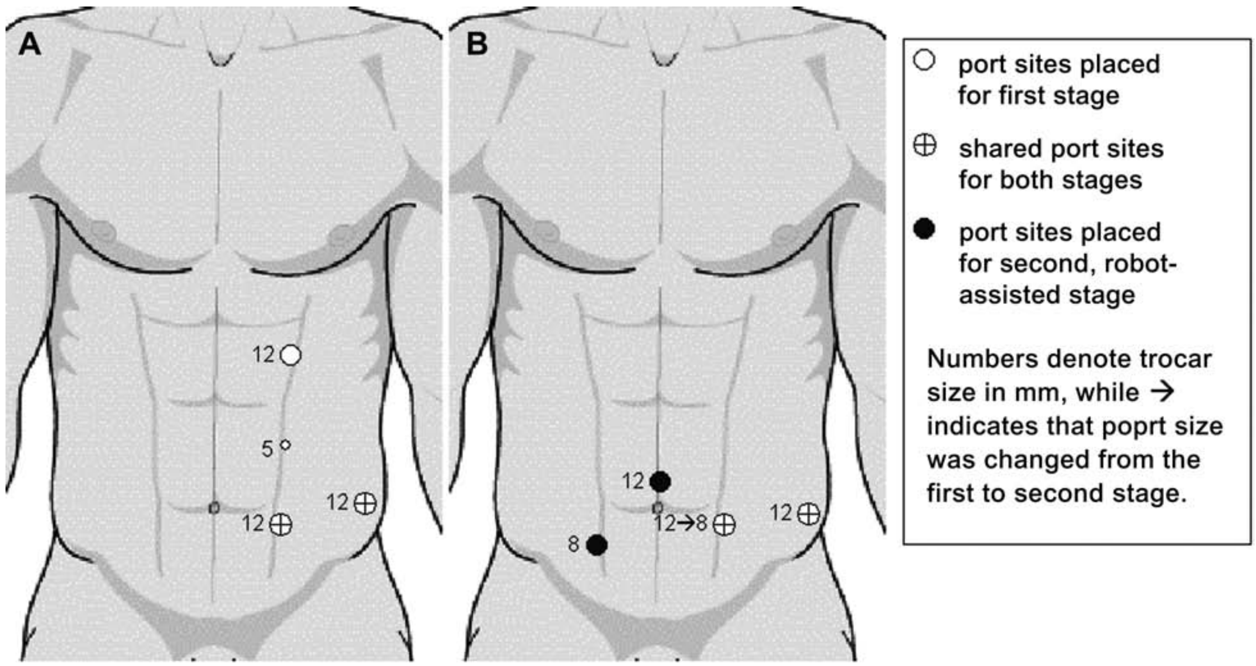

FIG. 1. (**A**) Diagram showing port placement used for the first stage of the transperitoneal approach for laparoscopic dissection of the kidney. (**B**) Diagram showing port placement used for the second stage, robot-assisted dissection of the distal ureter and closure of the cystotomy.

limited range of motion of the robotic arms and the potential for the robotic arms to collide with one another. First, a minimum distance of 8 cm was maintained between the robotic port sites. Second, the ureter was dissected out as distally as possible during the first purely laparoscopic stage, ideally over the common iliac artery. To achieve this objective, the white line of Toldt must be incised as caudad as possible to reflect the colon medially. Inability to dissect the ureter into the pelvis may result in limited range of motion of the robotic arms in reaching cephalad while dissecting the mid-ureter. Furthermore, limiting the robotic portion of the procedure to a triangulated dissection of the distal ureter and bladder cuff also minimizes the likelihood of robotic arm collisions while in the flank position. Finally, avoiding the need to reposition and dock the robot in flank position not only shortened operative time, but also improved exposure for the distal ureterectomy and closure of the bladder cuff by allowing gravity to displace the bowel away from the distal ureter, particularly for patients with high BMI.

RESULTS

Flexible cystoscopy did not demonstrate any abnormalities of the bladder mucosa, and minimally-invasive nephroureterectomy was completed without open conversion. Demographic characteristics of the study population are presented in Table 1. The mean age was 64.2 years, and the mean BMI was 28.4 kg/m^2. There were five right-sided and four left-sided tumors. Three patients had a history of previous abdominal surgery, including open cholecystectomy and appendectomy, hysterectomy, and distal ureterectomy and psoas hitch for distal ureteral TCC, respectively.

The operative data are presented in Table 2. The mean operative time was 303 minutes (range 210–430 minutes), and mean operative time with and without repositioning from flank to lithotomy position was 413 minutes (range 305–505 minutes) *v* 229 minutes (range 210–292 minutes). Mean estimated blood loss was 211 mL (range 50–700 mL), and one patient was transfused one unit of blood due to advanced age and a hematocrit <30. There were no intraoperative or postoperative complications. Mean length of stay was 2.3 days (range 2–4 days), and mean duration of bladder catheterization was 5 days.

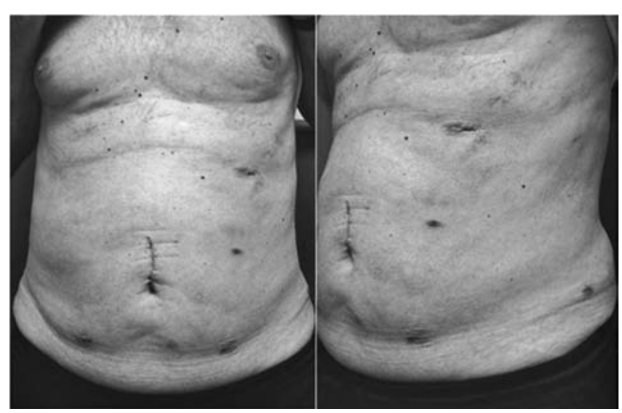

FIG. 2. One-week postoperative ventral and oblique views of the wound sites.

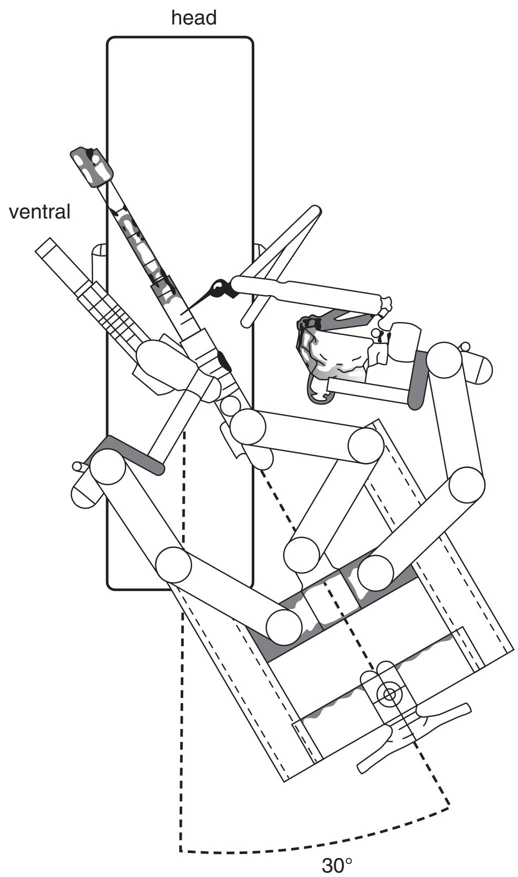

FIG. 3. Robot docking diagram.

On pathologic analysis, pT_3 TCC was detected in five patients (55.6%), CIS in two patients (22.2%), and pT_a in two others (22.2%). High-grade disease was identified in seven patients (77.8%), while the other two (22.2%) were found to have low-grade disease. There was one positive margin at the bladder cuff in a patient with a history of multifocal TCC of the bladder.

Of the four men with a history of superficial bladder cancer prior to laparoscopic nephroureterectomy, three developed recurrence in the bladder. Two men underwent transurethral resection of superficial bladder cancer at 4 and 6 months following laparoscopic nephroureterectomy. In addition, one of these men had evidence of metastatic lesions in the liver and retroperitoneal lymphadenopathy 5 months following laparoscopic nephroureterectomy. Finally, the patient with a history of superficial distal ureteral and bladder cancer status post–distal ureterectomy, psoas hitch, and laparoscopic nephroureterectomy developed muscle-invasive bladder TCC, and underwent radical cystectomy 12 months after laparoscopic nephroureterectomy. Mean follow-up for the series was 13.2 months (range 1.3–21.3 months).

DISCUSSION

Transitional cell carcinoma of the upper tract is less common than TCC of the lower tract and has fewer surgical options. Although endoscopic treatments have been described,[1] the gold standard therapy is nephroureterectomy. Laparoscopic *v* open nephroureterectomy has been described to have lower blood loss, less postoperative pain, and shorter hospital stay, and both types have similar recurrence rates.[4–10] In addition, potential disadvantages of open nephroureterectomy include contralateral ureteral orifice compromise, inadequate excision of the entire ureter and bladder cuff, and technical difficulty in obese patients.[11,12] Laparoscopic nephroureterectomy has been described with considerable variation in the excision of the distal ureter and bladder cuff. The five main techniques that have been described combine open, laparoscopic, and endoscopic modalities including open, transvesical detachment and ligation, laparoscopic stapling of the distal ureter and bladder cuff,

Table 2. Operative Data

Patient	*Operative (minutes)*	*Estimated blood loss (mL)*	*Change in hematocrit*	*Change in creatinine*	*Length of stay (days)*	*Pathology*	*Margins*	*Repositioning between first and second stage*
1	303	50	5.1	0.5	2	T_3 renal pelvis	Negative	Yes
2	513	300	2.3	0.5	2	CIS renal pelvis	Negative	Yes
3	465	300	11.3	0.3	4	T_a ureter	Negative	Yes
4	505	700	15.9	−0.3	3	T_a ureter	Positive	Yes
5	313	50	−0.3	0.4	2	T_3 renal pelvis and proximal ureter	Negative	Yes
6	252	200	7.6	0.2	2	T_3 of ureter N_1	Negative	No
7	380	100	6.0	0.1	2	CIS high-grade distal ureter	Negative	Yes
8	225	100	5.8	0.9	2	T_3 renal pelvis invaded renal parenchyma	Negative	No
9	210	100	4.4	0.3	2	T_3 renal pelvis invaded renal parenchyma	Negative	No

the pluck technique, and ureteral intussusceptions.[3,7,10,11] We believe that the use of extravesical robot-assisted laparoscopic excision of the distal ureter and bladder cuff is also a viable alternative to open nephroureterectomy.

Rose and colleagues initially described the use of robot-assisted laparoscopic nephroureterectomy.[13] Both patients underwent retroperitoneoscopic nephroureterectomy with a mean operative time of 182.5 minutes and mean blood loss of 75 mL with no perioperative complications. Another series of 10 patients underwent laparoscopic nephroureterectomy and robot-assisted transvesical excision of the distal ureter and bladder cuff.[14] Our approach differs with flexible cystosocopy initially performed to survey the bladder mucosa, followed by laparoscopic nephroureterectomy and robot-assisted extravesical distal ureterectomy and closure of the cystotomy. Although we did not encounter any bladder tumors when we surveyed initially with flexible cystoscopy, such a finding could be managed with transurethral resection prior to laparoscopic nephroureterectomy. Furthermore, the extravesical *v* transvesical approach may decrease the potential for tumor spillage from the bladder, obviate the need for a drain, shorten the duration of bladder catheterization, and minimize hematuria postoperatively.

Another issue related to nephroureterectomy is the efficacy of performing retroperitoneal lymph node dissection at the time of surgery. Although we did not perform concurrent lymph node dissection in our series, Brausi and associates demonstrated the potential benefits of performing a node dissection at the time of open nephrouretectomy.[15] They found that the time to recurrence for those that did *v* those that did not undergo lymph node dissection to be longer (51.2 *v* 18.5 months), and the overall survival to be greater (52.5 *v* 21.2 months). Additional studies are needed to define the role of concurrent lymph node dissection with nephroureterectomy.

Our study has several limitations. First, our study is not a prospective randomized trial, which limits our ability to compare outcomes and costs with alternate surgical approaches. We feel that the potential disadvantages of this approach compared to those of conventional laparoscopy (i.e., the additional time to dock and the cost of the robotic approach) are offset by the ease of robot-assisted *v* conventional laparoscopic dissection of the distal ureter and intracorporeal suturing to close the cystotomy. These advantages may result in a more watertight closure that shortens the duration of catheterization. In an era of ever-growing health care costs, the use of the robot for distal dissection of the distal ureter raises concerns about cost-effectiveness. While there are no comparisons of nephroureterectomy by surgical approach, Lotan and colleagues evaluated some cost components of laparoscopic and robot-assisted laparoscopic prostatectomy, and compared their costs to those of open radical retropubic prostatectomy.[16] Retropubic radical prostatectomy was the most cost-effective approach, with a cost advantage of $487 and $1726 over the laparoscopic and robotic groups, respectively. Conversely, Mouraviev and associates recently described cost advantages for robot-assisted laparoscopic *v* open radical prostatectomy, due to fewer transfusions and shorter lengths of stay.[17]

Second, we do not have follow-up for long-term cancer control; however, our short-term outcomes such as length of stay, blood loss, and pathologic outcomes compare favorably to those of other approaches for nephroureterectomy. Although our series is small to date, we believe that minimally-invasive nephroureterectomy with extravesical robot-assisted distal ureterectomy and closure of cystotomy closely approximates the oncologic outcomes of the open approach, with less morbidity. The technical challenge of intracorporeal laparoscopic reconstruction of the cystotomy is greatly diminished with the use of the robot. While operative times were initially long, it decreased by an average of 2 hours with increased familiarity with the approach, and by eliminating the step of repositioning from flank to lithotomy position.

CONCLUSION

Minimally-invasive nephroureterectomy with robot-assisted distal ureterectomy is a safe, consistently reproducible alternative for upper tract transitional cell carcinoma. However, longer follow-up is warranted to compare oncologic outcomes with those of open and other minimally-invasive techniques.

REFERENCES

1. Clayman RV, Kavoussi LR, Figenshau RS, et al. Laparoscopic nephroureterectomy: Initial clinical case report. J Laparoendosc Surg 1991;1:343–349.
2. Steinberg JR, Martin SF. Laparoscopic radical nephroureterectomy: Dilemma of the distal ureter. Curr Opin Urol 2004;14:61–65.
3. Gill IS, Schweizer D, Hobart MG, et al. Retroperitoneal laparoscopic radical nephrectomy: The Cleveland Clinic experience. J Urol 2000;163:1665–1670.
4. Chen GL, Bagley DH. Ureteroscopic surgery for upper tract transitional-cell carcinoma: Complications and management. J Endourol 2001;15:399–404.
5. Goel A, Hemal AK, Gupta NP. Retroperitoneal laparoscopic radical nephrectomy and nephroureterectomy and comparison with open surgery. World J Urol 2002;20:219–223.
6. Klingler HC, Lodde M, Pycha A, et al. Modified laparoscopic nephroureterectomy for treatment of upper tract transitional cell cancer is not associated with an increased risk for tumor recurrence. Eur Urol 2003;44:442–447.
7. McDougall EM, Clayman RV, Elashry O. Laparoscopic nephroureterectomy for upper tract transitional cell cancer: The Washington University experience. J Urol 1995;154:975–980.
8. Kawauchi A, Fujito A, Ukimura O, et al. Hand assisted retroperitoneoscopic nephroureterectomy: Comparison with the open procedure. J Urol 2003;169:890–894.
9. Stifelman MD, Hyman MJ, Shichman S, Sosa RE. Hand assisted laparoscopic nephroureterectomy versus open nephroureterectomy for the treatment of transitional cell carcinoma of the upper urinary tract. J Endourol 2001;15:391–395; discussion 397.
10. Tan BJ, Ost MC, Lee BR. Laparoscopic nephroureterectomy with bladder cuff resection: Techniques and outcomes. J Endourol 2005;19:664–676.
11. Matsui Y, Ohara H, Icihoka K, et al. Retroperitoneoscopy assisted total nephroureterectomy for upper urinary tract transitional cell carcinoma. Urology 2002;60:1010–1015.
12. Uozumi J, Fujiyama C, Meiri H, et al. Hand assisted retroperitoneoscopic nephroureterectomy for upper tract urothelial tumors. J Endourol 2002;16:743–747.

13. Rose K, Khan S, Godbole H, Olsburgh J, Dasgupta P, et al. Robotic-assisted retroperitoneoscopic nephroureterectomy. Int J Clin Pract 2006;60:12–14.
14. Nanigian DK, Smith W, Ellison LM. Robotic-assisted laparoscopic nephroureterectomy. J Endourol 2006;7:463–465.
15. Brausi MA, Gavioli M, De Luca G, Verrini G, Peracchia G, Simonini G, Viola M. Retroperitoneal lymph node dissection (RPLD) in conjunction with nephroureterectomy in the treatment of infiltrative transitional cell carcinoma (TCC) of the upper urinary tract: Impact on survival. Eur Urol 2007;52:1414–1418.
16. Lotan Y, Cadeddu JA, Gettman MT. The new economics of radical prostatectomy: Cost comparison of open, laparoscopic and robotic assisted techniques. J Urol 2004;172:1431–1435.
17. Mouraviev V, Nosnik I, Sun L, et al. Financial comparative analysis of minimally invasive surgery to open surgery for localized prostate cancer: A single-institution experience. Urology 2007;69: 311–314.

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ABBREVIATIONS USED

BMI = body mass index; CIS = carcinoma *in situ*; TCC = transitional cell carcinoma.

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Partial Clamping of the Renal Artery During Robot-Assisted Laparoscopic Partial Nephrectomy: Technique and Initial Outcomes

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Abstract

Purpose: We describe the feasibility of partial arterial clamping (PAC) during robot-assisted partial nephrectomy (RAPN).

Patients and Methods: We undertook a retrospective study of five patients who underwent PAC *vs* 17 who underwent complete hilar clamping (CHC). Estimated blood loss (EBL), transfusion rate, operative/console time, warm ischemia time (WIT), pathology, and postoperative glomerular filtration rate (GFR) were compared.

Results: PAC patients were older ($P=0.002$) and more likely to have had previous abdominal surgeries ($P=0.032$). PAC *vs* CHC was associated with higher median EBL (350 mL *vs* 75 mL, $P=0.026$), although there were no differences in blood transfusions ($P=0.250$). PAC was associated with shorter WIT (14 min *vs* 21 min, $P=0.023$). Positive margin rate and GFR change were similar.

Conclusions: PAC offers a simple and reproducible technique that limits WIT during RAPN. PAC was not associated with more transfusions or positive margins. Further study is warranted to determine the utility of PAC with larger tumor size as well as the long-term benefits on renal function.

Introduction

Partial nephrectomy (PN) is the gold standard for management of localized renal cortical tumors,[1] offering comparable oncologic outcomes *vs* radical nephrectomy (RN)[2–4] while conferring improved overall survival because of avoidance of postoperative renal insufficiency.[5–8] Technical difficulties of laparoscopic PN, however, have led to decreased use relative to laparoscopic RN.[9] The introduction of robot-assisted radical nephrectomy (RAPN) has mitigated many of these potential barriers,[10,11] although technical challenges remain in limiting warm ischemia time (WIT).

More than 20 minutes of complete renal arterial clamping leads to diminished renal function.[12] Technical modifications of hilar control and renorrhaphy to reduce or even eliminate WIT have been described.[13–15] We describe our initial experience with partial arterial clamping (PAC) during RAPN to attenuate WIT while maintaining vascular control to demonstrate that this is a feasible and reproducible technique.

Patients and Methods

Patient enrollment

Between 2006 and 2011, 40 PNs were performed by a single surgeon (JCH). In 2011, we performed RAPN with PAC in five consecutive patients. For comparison purposes, we excluded open and laparoscopic PN, those undergoing PN without hilar clamping, those with unrecorded WIT (n=3), and one RAPN performed for nonfunction in a duplicated system. The final cohorts consisted of 17 RAPN with complete hilar (renal arterial and venous) clamping (CHC) *vs* 5 with PAC. Data were prospectively collected by research personnel uninvolved with clinical care and entered into a database approved by the Institutional Review Board.

Surgical technique

We performed RAPN consistent with previous descriptions of port placement and technique.[10,14] Monopolar scissor and bipolar Maryland currents are set to 25 W. The tumor is identified using preoperative imaging.

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FIG. 1. A bulldog clamp is applied to the right renal artery such that only 50% or less of the renal artery diameter is clamped. The assistant suction tip is used to retract the lower pole of the kidney anteriorly.

Intraoperative ultrasonography is used only for endophytic tumors. The margin of planned resection is landmarked by circumferentially scoring the surrounding renal capsule with monopolar current. Before PAC and tumor resection, the left bipolar Maryland dissector is replaced with ProGrasp™ (Intuitive Surgical, Sunnyvale, CA) forceps. Furosemide and mannitol are administered. A laparoscopic bulldog clamp is applied by the assistant such that approximately 50% or less of the arterial diameter is occluded. The renal vein is left unclamped (Figs. 1 and 2). The tumor is then resected with cold scissors. During excision, there is moderate bleeding, but visualization remains adequate with suction performed by the assistant.

Two-layer renorrhaphy is performed. First, the base of the renal defect is repaired with a running 3-0 polyglactin suture on a CT-3 needle with a Lapra-Ty® (Ethicon, Cincinatti, OH) applied to the tail. This initial suture is used to ligate bleeding arterioles evident during PAC as well as collecting system defects. A second Lapra-Ty is applied to maintain suture line tension on the base repair. A modification of the sliding-clip

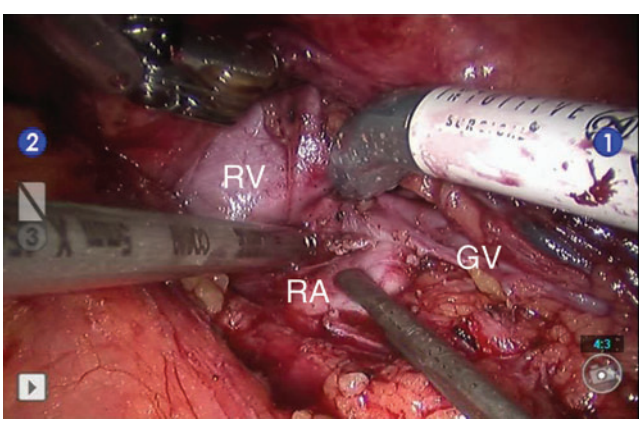

FIG. 2. Intraoperative image of partial arterial clamping of the left renal artery.

FIG. 3. A two layer renorrhaphy is used. The base of the defect is first repaired with a running 3-0 polyglactin suture, encompassing bleeding arterioles as well as collecting system defects. After the first layer of closure, the bulldog clamp is removed. A running sliding clip renorrhaphy is then used.

renorrhaphy is used[14] for the second layer of the renorrhaphy with a running *vs* interrupted suture line using 0 polyglactin on a CT-1 needle (Fig. 3). After the corner bite is placed, the laparoscopic bulldog clamp is removed, and the sliding-clip technique is used with each running bite. In the CHC group, we removed the clamp after completion of the sliding-clip renorrhaphy in contrast to earlier unclamping with PAC. We avoid bolsters during renorrhaphy because of concern of resulting potential space after bolster reabsorption contributing to pseudoaneurysm formation.

Outcomes

Perioperative outcomes were prospectively recorded and included estimated blood loss (EBL), blood transfusion, operative and robotic console time, WIT, final pathologic diagnosis, and positive margins. Postoperative glomerular filtration rate (GFR) was measured using the Modification of Diet in Renal Disease equation with the most recent creatinine values and a median follow-up of 15 months.

Statistical analysis

Baseline demographic, perioperative, and pathologic data were compared using the Kruskal-Wallis test for medians and the Fisher exact test for proportions.

Results

Table 1 summarizes preoperative characteristics and intraoperative outcomes. Patients undergoing PAC were older ($P=0.002$) and more likely to have had previous abdominal surgeries ($P=0.032$). There were no significant differences in tumor location. PAC *vs* CHC was associated with significantly higher median EBL (350 mL *vs* 75 mL, $P=0.026$), although there were no differences in blood transfusion rate ($P=0.250$). PAC was associated with shorter clamp times

Table 1. Preoperative Characteristics and Intraoperative Outcomes

	Partial artery clamping *n=5*	*Complete hilar clamping* *n=17*	P *value*
Preoperative characteristics			
Median (interquartile range)			
Age, years	62.7 (44.5–75.5)	57.1 (31.2–78.5)	0.906
Body mass index, kg/m^2	31.2 (22.9–35.7)	25.2 (22.7–34.1)	0.926
Radiographic tumor size, cm	2.3 (1.5–3.5)	3.0 (1.7–5.3)	0.254
n (%)			
Race			
White	5 (100)	13 (76.5)	0.999
Black	0 (0)	2 (11.8)	
Other	0 (0)	2 (11.8)	
Sex			
Male	4 (80)	11 (64.7)	0.999
Female	1 (20)	6 (35.3)	
Tumor laterality			
Right	4 (80)	10 (58.8)	0.613
Left	1 (20)	7 (41.2)	
Tumor polarity			
Upper pole	2 (40)	5 (29.4)	0.541
Midpolar	0 (0)	5 (29.4)	
Lower pole	3 (60)	7 (41.2)	
>50% Exophytic	5 (100)	13 (76.5)	0.535
Previous abdominal surgery	3 (60)	1 (5.9)	0.032
Intraoperative outcomes			
Median (interquartile range)			
Estimated blood loss, mL	350 (150–400)	75 (50–150)	0.026
Operative time, min	157.5 (147–186)	150 (133–157.5)	0.389
Console time, min	127.5 (117–156)	120 (95–130)	0.506
Warm ischemia time, min	14 (13–15)	21 (19–25)	0.020
n (%)			
Transfusion	1 (20)	0 (0)	0.227

(14 min *vs* 21 min, $P=0.023$), attributable to earlier unclamping during renorrhaphy.

Pathologic and renal functional outcomes are summarized in Table 2. There were no significant differences in pathologic outcomes or positive margins. Preoperative and postoperative GFR changes did not differ between the PAC *vs* CHC cohorts. The potential benefit of PAC, however, was exemplified in the first case of the series, in which preoperative GFR decreased from 64 to 56 on postoperative day 2 after RAPN for a 3.4 cm lower pole mass in a solitary kidney.

Discussion

PN confers the benefits of better long-term renal function and overall survival while achieving equivalent oncologic outcomes *vs* RN.[1,5] Moreover, PN is associated with a lower risk of coronary artery disease, anemia, and bone loss.[6] In addition, even with prolonged WIT, patients undergoing PN *vs* RN have better postoperative renal function.[16] Therefore, PN by any surgical approach is the preferred approach to renal tumors.[1]

Table 2. Pathologic and Renal Functional Outcomes

	Partial artery clamping *n=5*	*Complete hilar clamping* *n=17*	P *value*
Pathologic outcomes, n (%)			
Pathologic subtype			
Clear cell	2 (40)	9 (52.9)	0.887
Papillary	2 (40)	4 (23.5)	
Chromophobe	0 (0)	2 (11.8)	
Oncocytoma	1 (20)	1 (5.9)	
Angiomyolipoma	0 (0)	1 (5.9)	
Positive margin	0 (0)	1 (5.9)	0.999
GFR, mean ± standard deviation			
Preoperative GFR	75.4 ± 25.8	67.8 ± 32.5	0.906
Postoperative GFR	65.6 ± 16.4	79.3 ± 18.5	0.106
GFR change	−9.8 ± 11.8	6.2 ± 23.5	0.123

GFR = glomerular filtration rate calculated using Modification of Diet in Renal Disease formula.

Although PN *vs* RN leads to better renal function regardless of WIT, efforts should be made to minimize WIT and maximize postoperative renal function.[12] Numerous techniques to attenuate or eliminate WIT have been described. Gill and associates[15] described "zero-ischemia" PN whereby segmental arterial branches feeding renal tumors are skeletonized and clamped, and the tumor is excised during a period of induced hypotension.[15] There may be some degree of ischemia to parenchyma surrounding the tumor with systemically reduced arterial pressure, however, and this may be difficult to reproduce outside of tertiary academic centers without consistent and experienced anesthesia colleagues. Moreover, greater surgical skill and risk of arterial injury and bleeding is involved with dissecting out segmental arteries.

A porcine series by Bensalah and colleagues[17] demonstrated the principle of PAC leading to a favorable renal oxygenation profile *vs* complete arterial clamping, and we set out to demonstrate this in clinical practice. This novel technique of PAC reduces arterial pressure to allow adequate visualization and allow tumor excision, as demonstrated in the referenced video.[18] This may be performed without need for systemic antihypertensive medications, which may carry some risk for those with coronary artery disease. If blood loss increases or visualization is poor during resection or repair with PAC, a second bulldog may be placed across the renal artery. Alternatively, conversion of PAC to CHC with reapplication of one bulldog clamp may be performed. While blood loss was predictably higher in PAC, this did not impede visualization, and there were no positive margins. In addition, transfusion rates did not differ significantly for PAC *vs* CHC, and the only transfusion was given preemptively after RAPN with PAC in an asymptomatic patient with a history of a five-vessel coronary artery bypass grafting. Although postoperative GFR changes did not vary significantly for PAC *vs* CHC, our small cases series may be underpowered and has limited follow-up. This technique, however, is relatively straightforward and reproducible outside of tertiary academic centers.

Hemodynamically, PAC reduces the functional diameter of the renal artery while continuing to permit blood flow to the kidney. According to the Bernoulli principle, an increase in the speed of a fluid leads to a corresponding decrease in a fluid's potential energy. In the case of constricted fluid flow, as occurs with PAC, fluid velocity increases with a corresponding decrease in the static pressure of the fluid to comply with the laws of fluid dynamics:

$$p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2)$$

where ρ is the density of the fluid, v_1 is the slower fluid velocity where the artery is wider, and v_2 is the faster fluid velocity where the artery is narrower. This is known as the Venturi effect.[19] In the case of PAC, while blood flow velocity may increase through the renal artery, it is at a lower pressure than if the artery were left unclamped. Physiologically, this drop in renal perfusion pressure may be accompanied by compensatory increased renin secretion from the juxtaglomerular apparatus, thus raising efferent arteriole resistance to maintain GFR. This needs to be studied and quantified in porcine or human models, however.

Our study must be considered in the context of the study design. First, this is a single surgeon case series that presents initial outcomes demonstrating the feasibility of a promising new technique and therefore may be underpowered to demonstrate improved renal functional outcomes. Further study is needed to compare long-term PAC *vs* CHC renal function. Second, this study was retrospective in nature and subject to the inherent limitations of retrospective data. Third, all tumors were exophytic and less than 3.5 cm in diameter. Further study is warranted for larger, endophytic tumors. PAC, however, supplements the armamentarium for arterial vascular control during PN, particularly for solitary kidneys.

Conclusions

PAC offers a simple and reproducible technique that limits ischemia during RAPN. We encourage its use in patients with preexisting renal insufficiency or with a solitary kidney in which any degree of ischemia may result in significant decline in renal function. Moreover, PAC avoids the greater complexity and risk associated with dissecting out segmental renal arteries or the anesthesia expertise and potential cardiac risks of systemic hypotension. We demonstrate that although there may be greater blood loss with PAC, it was not associated with more transfusions or positive margins. Further study is warranted to determine long-term benefits on postoperative renal function.

Disclosure Statement

No competing financial interests exist.

References

1. Campbell SC, Novick AC, Belldegrun A, et al. Guideline for management of the clinical T1 renal mass. J Urol 2009;182: 1271–1279.
2. Lee CT, Katz J, Shi W, et al. Surgical management of renal tumors 4 cm. or less in a contemporary cohort. J Urol 2000; 163:730–736.
3. Lau WK, Blute ML, Weaver AL, et al. Matched comparison of radical nephrectomy vs nephron-sparing surgery in patients with unilateral renal cell carcinoma and a normal contralateral kidney. Mayo Clin Proc 2000;75:1236–1242.
4. Thompson RH, Siddiqui S, Lohse CM, et al. Partial versus radical nephrectomy for 4 to 7 cm renal cortical tumors. J Urol 2009;182:2601–2606.
5. Weight CJ, Larson BT, Fergany AF, et al. Nephrectomy induced chronic renal insufficiency is associated with increased risk of cardiovascular death and death from any cause in patients with localized cT1b renal masses. J Urol 2010;183: 1317–1323.
6. Lane BR, Poggio ED, Herts BR, et al. Renal function assessment in the era of chronic kidney disease: Renewed emphasis on renal function centered patient care. J Urol 2009;182: 435–444.
7. Huang WC, Elkin EB, Levey AS, et al. Partial nephrectomy versus radical nephrectomy in patients with small renal tumors—is there a difference in mortality and cardiovascular outcomes? J Urol 2009;181:55–62.
8. Thompson RH, Boorjian SA, Lohse CM, et al. Radical nephrectomy for pT1a renal masses may be associated with decreased overall survival compared with partial nephrectomy. J Urol 2008;179:468–473.
9. Hollenbeck BK, Taub DA, Miller DC, et al. National utilization trends of partial nephrectomy for renal cell carcinoma: A case of underutilization? Urology 2006;67:254–259.

10. Caruso RP, Phillips CK, Kau E, et al. Robot assisted laparoscopic partial nephrectomy: Initial experience. J Urol 2006;176:36–39.
11. Rogers CG, Singh A, Blatt AM, et al. Robotic partial nephrectomy for complex renal tumors: Surgical technique. Eur Urol 2008;53:514–521.
12. Thompson RH, Lane BR, Lohse CM, et al. Every minute counts when the renal hilum is clamped during partial nephrectomy. Eur Urol 2010;58:340–345.
13. Nguyen MM, Gill IS. Halving ischemia time during laparoscopic partial nephrectomy. J Urol 2008;179:627–632.
14. Benway BM, Wang AJ, Cabello JM, Bhayani SB. Robotic partial nephrectomy with sliding-clip renorrhaphy: Technique and outcomes. Eur Urol 2009;55:592–599.
15. Gill IS, Eisenberg MS, Aron M, et al. "Zero ischemia" partial nephrectomy: Novel laparoscopic and robotic technique. Eur Urol 2011;59:128–134.
16. Lane BR, Fergany AF, Weight CJ, Campbell SC. Renal functional outcomes after partial nephrectomy with extended ischemic intervals are better than after radical nephrectomy. J Urol 2010;184:1286–1290.
17. Bensalah K, Raman JD, Zeltser IS, et al. A comparison of kidney oxygenation profiles between partial and complete renal artery clamping during nephron sparing surgery in a porcine model. Can J Urol 2009;16:4632–4638.
18. Kowalczyk K, Alemozaffar M, Hu J. Partial clamping of the renal artery during robotic-assisted laparoscopic partial nephrectomy: Technique and initial outcomes. 2011. www.youtube.com/watch?v=SH6FExW_RdE. Accessed July 20, 2011.
19. Lamb H. Hydrodynamics. 6th ed. Cambridge University Press; 1953.

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Abbreviations Used

CHC = complete hilar clamping
EBL = estimated blood loss
GFR = glomerular filtration rate
PN = partial nephrectomy
PAC = partial arterial clamping
RAPN = robot-assisted partial nephrectomy
RN = radical nephrectomy
WIT = warm ischemia time

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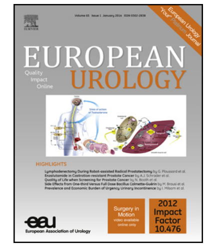

European Association of Urology

Surgery in Motion

Technique and Outcomes of Robot-assisted Retroperitoneoscopic Partial Nephrectomy: A Multicenter Study

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Please visit www.europeanurology.com and www.urosource.com to view the accompanying video.

Abstract

Background: Robot-assisted retroperitoneoscopic partial nephrectomy (RARPN) may be used for posterior renal masses or with prior abdominal surgery; however, there is relatively less familiarity with RARPN.
Objective: To demonstrate RARPN technique and outcomes.
Design, setting, and participants: A retrospective multicenter study of 227 consecutive RARPNs was performed at the Swedish Medical Center, the University of Michigan, and the University of California, Los Angeles, from 2006 to 2013.
Surgical procedure: RARPN.
Outcome measurements and statistical analysis: We assessed positive margins and cancer recurrence. Stepwise regression was used to examine factors associated with complications, estimated blood loss (EBL), warm ischemia time (WIT), operative time (OT), and length of stay (LOS).
Results and limitations: The median age was 60 yr (interquartile range [IQR]: 52–66), and the median body mass index (BMI) was 28.2 kg/m^2 (IQR: 25.6–32.6). Median maximum tumor diameter was 2.3 cm (IQR: 1.7–3.1). Median OT and WIT were 165 min (IQR: 134–200) and 19 min (IQR: 16–24), respectively; median EBL was 75 ml (IQR: 50–150), and median LOS was 2 d (IQR: 1–3). Twenty-eight subjects (12.3%) experienced complications, three (1.3%) had urine leaks, and three (1.3%) had pseudoaneurysms that required reintervention. There was one conversion to radical nephrectomy and three transfusions. Overall, 143 clear cell carcinomas (62.6%) composed most of the histology with eight positive margins (3.5%) and two recurrences (0.9%) with a median follow-up of 2.7 yr. In adjusted analyses, intersurgeon variation was associated with complications (odds ratio [OR]: 3.66; 95% confidence interval, 1.31–10.27; $p = 0.014$) and WIT (parameter estimate [PE; plus or minus standard error]: 4.84 ± 2.14; $p = 0.025$). Higher surgeon volume was associated with shorter WIT (PE: -0.06 ± 0.02; $p = 0.002$). Higher BMI was associated with longer OT (PE: 2.09 ± 0.56; $p < 0.001$). Longer OT was associated with longer LOS (PE: 0.01 ± 0.01; $p = 0.002$). Finally, there was a trend for intersurgeon variation in OT (PE: 18.5 ± 10.3; $p = 0.075$).
Conclusions: RARPN has acceptable morbidity and oncologic outcomes, despite intersurgeon variation in WIT and complications. Greater experience is associated with shorter WIT.
Patient summary: Robot-assisted retroperitoneoscopic partial nephrectomy has acceptable morbidity and oncologic outcomes, and there is intersurgeon variation in warm ischemia time and complications.

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1. Introduction

The incidence of small renal masses has been increasing, and partial nephrectomy has become the gold standard for the treatment of T1a (<4 cm) renal tumors in the setting of a normal contralateral kidney [1]. Although there is greater acknowledgment that nephron-sparing approaches are underused [2], most partial nephrectomies are performed through an open approach despite the lower morbidity and shorter hospitalization of minimally invasive surgery. For instance, the open, robotic, and laparoscopic approaches accounted for 79%, 11.5%, and 9.5%, respectively, of all partial nephrectomies performed in the United States in 2008 [3].

Tumor location factors into treatment decision making. Some centers prefer percutaneous thermal ablation for posterior and lateral tumors [4]; others prefer a retroperitoneoscopic partial nephrectomy approach [5]. Although the retroperitoneoscopic approach was first described by Gaur et al. in 1993 [6], there has been relatively less adoption and utilization compared with transperitoneal laparoscopic approaches. This may be due to larger working space and more anatomic landmarks afforded by the transperitoneal laparoscopic approach. However, transperitoneal access to posterior renal tumors requires bowel mobilization and full kidney mobilization to flip the kidney medially, which may challenge the field of view due to the proximity of the renal mass to the laparoscope. Conversely, the retroperitoneal approach is limited by a smaller working space, and the absence of anatomic landmarks may disorient and risk inadvertent vascular injury requiring open conversion [7]. However, this approach also minimizes the risk of bowel injury, particularly with prior abdominal surgery.

Given the challenging learning curve of minimally invasive and robotic surgery and less use of retroperitoneoscopic minimally invasive surgery, the objective of our study was to illustrate our surgical approach and outcomes with robot-assisted retroperitoneoscopic partial nephrectomy (RARPN) to facilitate its adoption.

2. Methods and patients

Our study was approved by the institutional review boards of the Swedish Medical Center (SMC); the University of California, Los Angeles (UCLA); and the University of Michigan (UM), and data were prospectively collected for 227 consecutive robot-assisted retroperitoneoscopic partial nephrectomies performed by J.P., J.C.H., and A.Z.W. from June 2006 to November 2013. All surgeons had performed conventional retroperitoneoscopy and >40 robot-assisted transperitoneal partial nephrectomies prior to initiating RARPN. Our initial approach to RARPN has been described [8,9], and we describe modifications and institutional variation with trocar placement and renorrhaphy. All attempted RARPNs were included without exclusion.

2.1. Surgical technique

2.1.1. Patient preparation

For retroperitoneal approaches, we do not administer bowel preps, and patients are limited to a clear liquid diet the day before surgery. A type and screen is sent before incision.

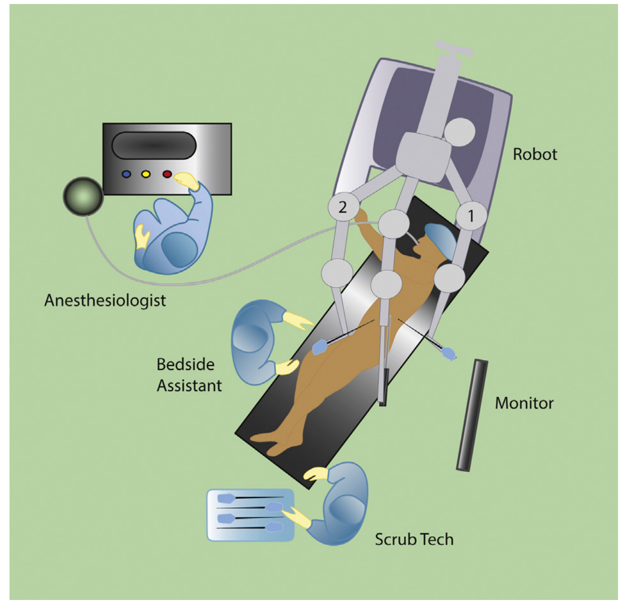

Fig. 1 – A long circuit may be needed by anesthesia to accommodate docking of the robot over the patient's head for robot-assisted retroperitoneoscopic partial nephrectomy.

2.1.2. Patient positioning

After intubation and bladder catheterization, patients are placed in full flank (decubitus position) with the ipsilateral side up relative to the renal tumor. In addition, an axillary roll is placed and the ipsilateral arm is secured with an airplane. The dependent arm is padded and secured close to the face to avoid blocking the robot from being docked in the best position. The bed is fully flexed to provide maximal space between the ribs and the iliac crest. The patient is secured with 4-inch cloth tape across the chest and pelvis. In addition, a long circuit is attached from the endotracheal tube to the ventilator to ensure adequate working space for the anesthesiologist in anticipation of the robot docking parallel and very close to the ipsilateral arm (Fig. 1).

2.1.3. Creation of retroperitoneal space and trocar placement

SMC and UCLA share the same trocar placement, whereas UM places the robotic trocars more cephalad; however, all institutions use the AirSeal System (SurgiQuest, Inc., Milford, CT, USA), which mitigates against inadvertent loss of pneumoretroperitoneum. All study surgeons did not use a fourth robotic arm due to the smaller working space and trocar distances of retroperitoneoscopy. At SMC and UCLA, a skin incision is made 1–2 cm above the iliac crest in the midaxillary line (Fig. 2A). At UCLA, a 12-mm trocar with a visual obturator and a zero-degree 10-mm laparoscope is used to tunnel through the subcutaneous adipose tissue, flank musculature, and the lumbodorsal fascia to the retroperitoneal fat. Alternatively, at SMC, blunt dissection is used to pop through the lumbodorsal fascial, and finger dissection is used to initialize creation of the retroperitoneal space. Next, the laparoscopic hernia balloon (Covidien OMSPDBS2, Mansfield, MA, USA) is inflated under direct laparoscopic vision. Care is taken to ensure that the kidney-shaped hernia balloon expands with its wings in a cranial-caudad direction posterior to the kidney. The ureter and gonadal vein are usually visualized with expansion of the balloon ventral to the psoas muscle. After full expansion, the hernia balloon is removed, and the 12-mm trocar is reinserted for insufflation of the retroperitoneum with 15 mm Hg of carbon dioxide (CO_2). The 8-mm robotic trocar is placed in the posterior axillary line in a horizontal plane approximately 2 cm cephalad to the 12-mm camera port. A laparoscopic Kittner is used to reflect the peritoneum medially and downward to allow

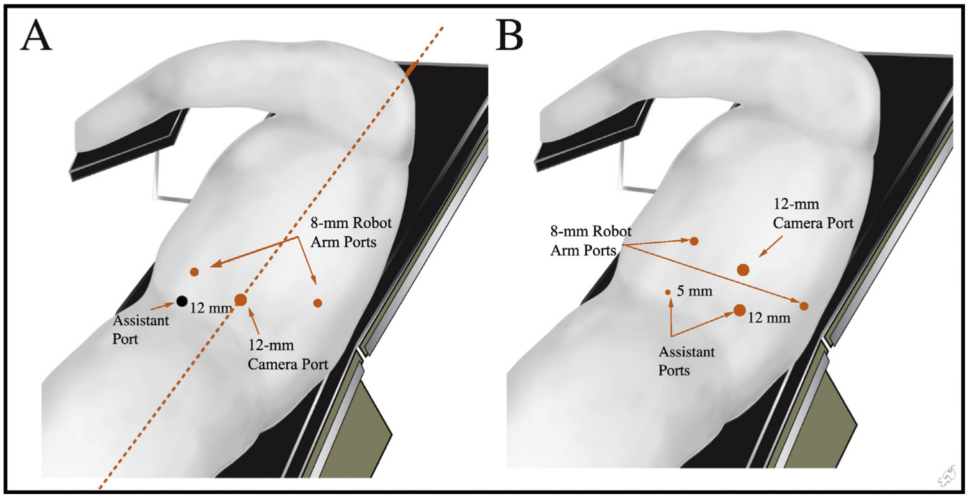

Fig. 2 – Trocar configuration: (A) University of California, Los Angeles, and the Swedish Medical Center; (B) University of Michigan.

insertion of a second 8-mm robotic trocar in the anterior axillary line in a horizontal plane approximately 1 cm caudad to the first robotic trocar. Finally, after ensuring the peritoneum is reflected 2 cm medial to the anterior superior iliac spine, a 12-mm assistant trocar is inserted at this location. The robot is docked (Fig. 1) over the forehead of the patient, and the robotic scope is inserted in the 12-mm initial access trocar while the hot scissors and fenestrated bipolar forceps are inserted into the posterior and anterior robotic trocars, respectively. A zero-degree robotic scope is used throughout the case.

At UM, a 2-cm skin incision is made below the tip of the 12th rib and a Schnidt Tonsil clamp is used to enter the thoracolumbar fascia and the retroperitoneal space, followed by blunt finger dissection behind the kidney (Fig. 2B). The hernia balloon is placed posterior to the kidney aimed toward the ipsilateral shoulder to expand the space. A conventional 12-mm trocar is then placed and the space is insufflated. Leak is prevented by filling the incision with petroleum gauze secured in place by a purse-string suture of the skin. The first robotic trocar is placed at the costovertebral angle, and a laparoscopic Kittner is used to mobilize the peritoneum medially to place the second robotic trocar 2 cm below the 11th rib. Assistant surgeon 12- and 5-mm trocars are placed on either side of the anterior superior iliac spine with a tendency to place the ports as medial as possible to allow the assistant to lift the kidney if needed in cases of peritoneal leak. In addition, the 30°-up robotic lens is used, which allows the assistant surgeon more space at the bedside.

2.1.4. *Renal artery dissection*

The robotic scope is rotated so the psoas courses horizontally, and Gerota fascia is incised horizontally approximately 1 cm above the psoas (Fig. 3). The fenestrated bipolar forceps is used to lift the kidney upward, putting the hilum on stretch to facilitate dissection through the perinephric fat onto the pulsations of the renal artery. The artery is skeletonized to allow subsequent selective versus nonselective renal artery clamping (Fig. 4), based on patient anatomy, with the laparoscopic bulldog clamp. This dissection is often performed with only the robotic scissors, and hooking perihilar connective tissue and applying monopolar current facilitates this one-handed approach. Alternatively, the bedside assistant may lift the kidney with the laparoscopic suction or a blunt instrument to free the fenestrated bipolar forceps, particularly with the UM two-assistant trocar approach. The renal artery is landmarked as the midpole reference point relative to the location of the renal mass on cross-sectional imaging. The renal vein is not routinely dissected out and clamped, with the exception of very central renal tumors encroaching on the venous vasculature.

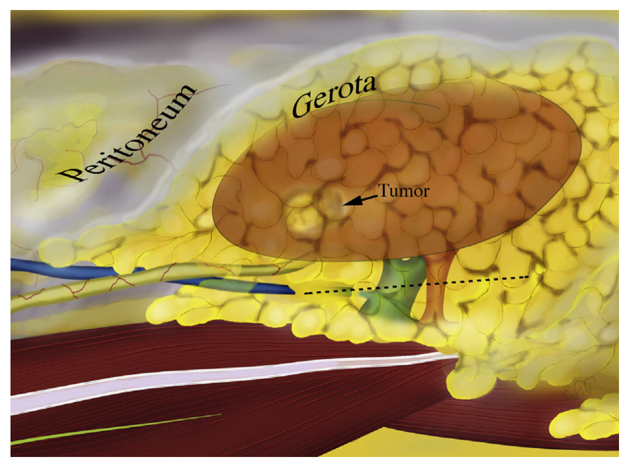

Fig. 3 – Retroperitoneal anatomic relationships. The robotic scope is turned so the psoas muscle is horizontal for orientation. In thinner patients, peristalsis of the ureter may be seen during and after balloon dissection of the retroperitoneum. Gerota fascia is incised horizontally above the psoas muscle.

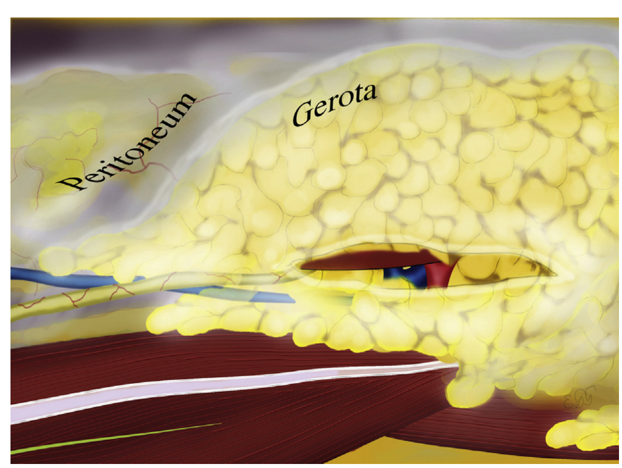

Fig. 4 – Arterial pulsations are helpful to identify the renal artery, which is skeletonized in anticipation of hilar vascular control.

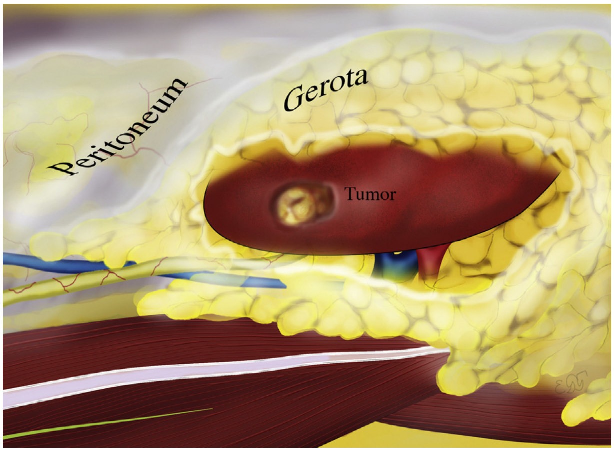

Fig. 5 – The hilum serves as a landmark relative to the tumor location, and the upper cut edge of Gerota fascia is used as a landmark to avoid inadvertent peritoneotomy. The kidney is defatted to identify the tumor.

Defatting of the kidney begins under the upper Gerota fascia cut edge, which is used as a landmark to avoid inadvertent peritoneotomy (Fig. 5). If there is CO_2 entry into the peritoneal space secondary to peritoneotomy and loss of the retroperitoneal space and exposure, a 5-mm trocar with a visual obturator may be inserted under direct laparoscopic vision to vent the peritoneal cavity; however, this was rarely required (two instances).

If we encounter difficulty with identifying the mass, we defat the kidney to identify its convex polar contour. Of note, tumors at the caudad extent of the kidney may be unreachable with the UM trocar placement and may require the transperitoneal approach.

Next, the laparoscopic ultrasound is used to identify and confirm tumor location, and cautery is used to circumscribe the planned renal capsule incision. Mannitol is administered (before indocyanine green in cases of selective renal artery clamping) prior to renal artery clamping. We go through a checklist to ensure there is adequate remaining use of the robotic needle drivers, the trocars have not backed out of their desired depth, and renorrhaphy sutures have been cut to the desired length and prepared to obviate the need for intracorporeal knot tying to minimize warm ischemia time (WIT). After clamping the main renal artery or a renal artery branch, cold scissor dissection is used to excise the tumor.

At UCLA, the first layer of the renorrhaphy is closed with a 3-0 barbed V-Loc suture (Covidien, Mansfield, MA, USA) in a running fashion, closing any collecting system injury and vascular structures. After placing the first bite of the second layer of the renorrhaphy with 2-0 absorbable polyfilament, the renal artery is unclamped and the horizontal mattress running suture is completed using the sliding clip technique [10]. At UM and SMC, a 4-0 absorbable monofilament is used to repair collecting system entry, and a 2-0 absorbable polyfilament is used to close sinus fat. A nitrocellulose bolster with two preplaced 0-absorbable polyfilament sutures is then secured with additional 0-absorbable polyfilament sutures to provide adequate compression, using the sliding clip technique, and hemostatic agents are used, if needed. The insufflation pressure is lowered to 5 mm Hg to ensure hemostasis prior to specimen and trocar removal and closure.

A 15F round drain is placed with collecting system entry through the more anterior 8-mm robotic trocar, after the specimen is placed into a laparoscopic bag and removed by enlarging the camera trocar incision. During wound closure, ketorolac is administered intravenously at UCLA, but not at UM or SMC.

2.2. *Statistical analyses*

Descriptive statistics were used to summarize our multicenter series. Stepwise logistic and linear regression was performed to adjust for independent variables such as age, body mass index (BMI), American Society of Anesthesiologists score, vascular variation (more than one renal artery or vein) nephrometry score, and surgeon volume (individual surgeon RARPN series ordinal case number). All tests were considered statistically significant at $\alpha = 0.05$. Statistical analyses were performed with SAS v.9.1.3 (SAS Institute, Cary, NC, USA).

3. Results

The median age was 60 yr (interquartile range [IQR]: 52–66), and the median BMI was 28.2 kg/m^2 (IQR: 25.6–32.6). Men composed 62.6% of the study sample, and a left renal mass was present in 119 (52.4%); 160 (70.5%) had a posterior location (Table 1). Twenty-nine of the subjects (12.8%) had a history of prior abdominal surgery. Most subjects had one renal artery (87.4%) and one renal vein (95.2%), respectively. Median maximum tumor diameter was 2.3 cm (IQR: 1.7–3.1), and most of the subjects (52.0%) had a nephrometry score between 5 and 8.

Median operative time (OT) and WIT were 165 min (IQR: 134–200) and 19 min (IQR: 16–24), respectively, and median length of stay (LOS) was 2 d (IQR: 1–3). The median intraoperative estimated blood loss (EBL) was 75 ml (IQR: 50–150), and three subjects required a transfusion (Table 2). Two subjects were transfused intraoperatively due to a high blood loss of 1600 ml and 2500 ml, respectively, and one of these subjects required conversion to radical nephrectomy due to refractory bleeding. Twenty-eight subjects (12.3%) experienced a complication. Six subjects required procedural intervention to correct Clavien grade 3 complications: three ureteral stent placements resolved urine leaks, and three pseudoaneurysms required angioembolization. Clear cell renal cell carcinoma (RCC) was identified in 143 subjects (62.6%), and there were eight (3.5%) positive surgical margins. Benign lesions were found in 45 subjects (19.8%). With a median follow-up of 2.7 mo, one subject with a positive surgical margin experienced a local recurrence; another subject with pT3a, negative margin, clear cell Fuhrman grade 4 developed metastases.

In adjusted analysis, there was significant intersurgeon heterogeneity for complications (odds ratio [OR]: 3.66; 95% confidence interval [CI], 1.31–10.27; $p = 0.014$) and WIT (parameter estimate [PE; plus or minus standard error]: 4.84 ± 2.14; $p = 0.025$). Higher surgeon volume was associated with shorter WIT (PE: -0.06 ± 0.02; $p = 0.002$). Higher BMI was associated with longer OTs (PE: 2.09 ± 0.49; $p < 0.001$); longer OTs were associated with longer LOS (PE: 0.01 ± 0.01; $p = 0.002$). Intersurgeon variation was associated with complications (OR: 3.66; 95% CI, 1.31–10.27; $p = 0.014$) and WIT (PE: 4.84 ± 2.14; $p = 0.025$). Higher surgeon volume was associated with shorter WIT (PE: -0.06 ± 0.02; $p = 0.002$). Higher BMI was associated with longer OT (PE: 2.09 ± 0.56; $p < 0.001$); longer OT was associated with longer LOS (PE: 0.01 ± 0.01; $p = 0.002$). Finally, older age was associated with higher EBL (PE: 4.53 ± 2.08; $p = 0.030$) and nephrometry score was not associated with outcomes of interest.

Table 1 – Characteristics of the study sample

	Median (IQR)
Age, yr	60 (52–66)
Body mass index, kg/m^2, median	28.2 (25.6–32.6)
Maximum tumor diameter, cm	2.3 (1.7–3.1)
Preoperative serum creatinine, mg/dl	1.0 (0.6–1.3)
Preoperative GFR, ml/min	74.7 (49.46–99.94)
	n (%)
Male gender	142 (62.6)
Comorbidities	
Coronary artery disease	44 (19.4)
Hypertension	95 (41.9)
Diabetes mellitus	39 (17.2)
ASA score	
1	4 (1.8)
2	123 (54.2)
3	95 (41.9)
Missing	5 (2.2)
Prior abdominal surgery	29 (12.8)
Solitary kidney	1 (1.2)
Left kidney	119 (52.4)
Number of arteries	
1	173 (87.4)
2	45 (19.8)
3	6 (2.6)
Missing	3 (1.3)
Veins	
1	216 (95.2)
2	11 (4.8)
Radius	
≤4 cm	149 (65.6)
>4 but <7 cm	62 (27.3)
≥7cm	14 (6.2)
Missing	2 (0.9)
Exophytic	
Completely endophytic	33 (14.5)
<50% exophytic	78 (34.4)
≥50% exophytic	78 (34.4)
Missing	38 (16.7)
Nearness to collecting system	
≥7 mm	60 (26.4)
>4 but <7 mm	37 (16.3)
≤4 mm	91 (40.2)
Missing	39 (17.3)
Location	
Anterior	14 (6.3)
Posterior	159 (70.0)
Neither	28 (12.3)
Missing	26 (11.5)
Location relative to polar line	
Entirely peripheral to polar line	70 (30.8)
Cross the polar line	53 (23.4)
>50% of mass crosses polar line	47 (20.7)
Missing	57 (25.1)
Nephrometry score	
≤4	13 (5.7)
5–8	117 (52.0)
9–12	39 (17.2)
Missing	58 (25.6)

ASA = American Society of Anesthesiologists; GFR = glomerular filtration rate; IQR = interquartile range.

Table 2 – Perioperative and pathologic outcomes

	Median (IQR)
Operation time, min	165 (134–200)
Warm ischemia time, min	19 (16–24)
EBL, ml	75 (50–150)
Length of stay, d	2 (1–3)
Postoperative serum creatinine, mg/dl	1.01 (0.59–1.43)
Postoperative GFR, ml/min	76.0 (50–102)
	n (%)
Collecting system entry	
No	175 (77.1)
Yes	52 (22.9)
Selective clamping*	
Selective clamping	39 (17.2)
Nonselective clamping	181 (79.7)
Unclamped fashion	7 (3.1)
Conversions	
Radical nephrectomy	1 (0.44)
Transperitoneal robotic partial nephrectomy	2 (0.88)
Perioperative complication	
Clavien grade 1	
Urinary retention	4 (1.76)
Urine leak	1 (0.44)
Acute kidney injury	1 (0.44)
Redness	1 (0.44)
Pain	2 (0.88)
Numbness from right flank to groin	1 (0.4)
Fever	1 (0.4)
Pneumothorax	1 (0.4)
Clavien grade 2	
Atrial fibrillation	1 (0.4)
Myocardial infarction	1 (0.4)
Pneumonia	3 (1.3)
Blood transfusion	3 (1.3)
Clavien grade 3	
Urine leak	3 (1.3)
Pseudoaneurysm	3 (1.3)
Histology	
No cancer	45 (19.8)
Clear cell	143 (62.6)
Papillary type	21 (9.23)
Chromophobe	14 (6.2)
Cystic RCC	1 (0.4)
Unclassified	2 (0.9)
Positive margin	8 (3.5)
Pathologic stage	
T1a	99 (54.4)
T1b	55 (30.2)
T2a	16 (8.8)
T3a	12 (7.6)

EBL = estimated blood loss; GFR = glomerular filtration rate; IQR = interquartile range; RCC = renal cell carcinoma.

4. Discussion

According to guidelines, surgical excision, thermal ablation, and active surveillance are treatment options for appropriately selected clinical T1 renal masses [11]. However, the guidelines do not preempt physician judgment in individual cases, and treatment decisions vary depending on an urologist's training, biases, comfort levels, and individual experience [12]. The significance of tumor location on treatment choice is reinforced by the categorization of anterior and posterior location by both the RENAL nephrometry and PADUA scores [13,14]. For instance, although anterior or posterior tumor location did not affect the likelihood of open partial nephrectomy complications [14], it affects physician recommendation for thermal ablation and minimally invasive approaches to nephron-sparing surgery [4]. Thermal ablation and partial nephrectomy appear to have comparable outcomes, but thermal ablation is associated with an eightfold greater use of surveillance imaging following treatment and greater frequency of computed tomography (CT) imaging. Radiation exposure increases the risk of secondary malignancies, and the costs of CT and magnetic resonance imaging contribute to the indirect health care costs of treating renal masses [15]. However, the use of thermal ablation to treat renal masses is increasing [16], and limited experience with the retroperitoneoscopy may contribute to referrals to radiologists for ablation of posteriorly and laterally located renal masses.

Our study has several important findings. First, we present a multicenter RARPN experience that is the largest to date and demonstrates significant variation in outcome by surgeon. Although all surgeons were fellowship trained in minimally invasive surgery, we demonstrate a significant heterogeneity in RARPN WITs and complications. For instance, after adjusting for nephrometry score and BMI and other observed differences in patient and tumor characteristics, one surgeon was significantly more likely to experience complications and had longer WITs by 4 min. This is significant given that longer WITs are associated with acute renal failure perioperatively and chronic kidney disease during long-term follow-up [17]. However, our WIT median of 19 min and IQR of 16–24 min is shorter than the 25-min cut-off established as a threshold for increased risk of acute renal failure and long-term stage IV chronic kidney disease [17].

Second, greater RARPN surgeon volume or experience was associated with shorter WITs. The surgeon volume–outcome relationship has been demonstrated for radical prostatectomy [18], radical cystectomy [19], and radical nephrectomy for RCC [20]. The learning curve for surgeons performing traditional laparoscopic partial nephrectomy has been estimated to be about 25 cases [21], with improved WIT noted with increasing surgical experience [22]. The transperitoneal robot-assisted partial nephrectomy learning curve for experienced robotic surgeons is similar at 20–30 cases required for acceptable outcomes [23]. However, these studies were single-surgeon series, and although we did not estimate a specific number for the RARPN learning curve due to our analysis of volume as a continuous variable, we demonstrate a clear association between RARPN surgeon volume and shorter WITs across multiple surgeons and institutions.

Third, our 3.5% likelihood of positive surgical margins is comparable with the published RARPN range of 0–5.6% [21,24–29], the 1.3–1.5% range for open partial nephrectomy [30,31], and the 2–7.1% range for laparoscopic retroperitoneal partial nephrectomy [32–34] (Table 3). In addition, our 0.9% recurrence rate is similar to the 1.5–6.0% range for these competing approaches to partial nephrectomy.

Fourth, higher BMI was associated with longer OTs. This finding parallels previous longer OTs among obese patients undergoing transperitoneal laparoscopic renal surgery [35] and transperitoneal robot-assisted partial nephrectomy [36]. However, obese versus nonobese patients have acceptable outcomes after retroperitoneal laparoscopic nephrectomy [37]. There may be an advantage to a retroperitoneal approach in the setting of high BMI because the retroperitoneal approach may bypass pannicular and intra-abdominal fat. For example, among extremely obese patients (BMI >40), retroperitoneal laparoscopic nephrectomy has less EBL and shorter OTs compared with the transperitoneal approach [38].Thus, although higher BMI was associated with longer OTs in our study, RARPN may have some advantages in this setting.

Finally, we demonstrate that the retroperitoneal approach is not associated with significant iatrogenic or overall complications, despite the intrinsically limited anatomic landmarks and greater familiarity with the

Table 3 – Surgical approach

Study	Sample size	Mean OT, min	Mean WIT, min	Mean EBL, ml	Mean LOS, d	Overall complications, %	Positive surgical margin, %	Cancer recurrence, %
Robot-assisted retroperitoneoscopic partial nephrectomy								
Hu et al.*	227	165	19	75	2	12.3	3.5	0.9
Open partial nephrectomy								
Gill et al. [30]	1029	258	20.1	376	5.8	13.7	1.3	1.5
Patard et al. [31]	600†	147	19.3	386	7.7	19.5	1.5	1.6†
Robot-assisted transperitoneal partial nephrectomy								
Ellison et al. [25]	108	215	24.9	368	2.7	33	5.6	0.9
Haber et al. [26]	75	200	18.2	323	4.2	16	1.3	NR
Jeong et al. [27]	31	170	20.9	198	5.2	NR	NR	6.4
Kural et al. [24]	11	185	26.5	286	3.9	9	0.0	0.0
Pierorazio et al. [21]	48	152	14.1	122	NR	10	4.2	NR
Seo et al. [28]	13	153	35.3	284	6.2	0	0.0	NR
Williams et al. [29]	27	233	18.5	180	2.5	22	0.4	NR
Laparoscopic retroperitoneal partial nephrectomy								
Marszalek et al. [32]	70	84	22.6	NR	5*	14	7.1	NR
Pyo et al. [33]	110	200	35	260	2.6	4.5‡	0.0	0.0
Ng et al. [34]	63	173	28.0	217	2.2	10	2.0	2

EBL = estimated blood loss; LOS = length of stay; NR = not reported; OT = operative time; WIT = warm ischemia time.
* Medians.
† For tumors ≤4 cm.
‡ Major complications.

transperitoneal approach. Our perioperative outcomes are comparable with alternative surgical approaches for nephron-sparing surgery (eg, open retroperitoneal, robot-assisted transperitoneal laparoscopic, and retroperitoneal laparoscopic approaches) (Table 3). The 1.3% likelihood of RARPN intraoperative complications—two transfusions due to high blood loss during renal mass excision and one self-resolving pneumothorax in our series—is comparable with the 2–10% reported for transperitoneal robot-assisted partial nephrectomy [39,40]. Together with our reported WIT, LOS, and EBL, our multisurgeon, multi-institutional RARPN study demonstrates that RARPN is safe and effective.

Our study must be interpreted in the context of the study findings. First, this is a retrospective study of prospectively collected surgeon data from fellowship-trained, high-volume surgeons at tertiary referral centers. As such, our results may not be applicable to the general urology population. Second, although we did not find an association between nephrometry score and outcomes, this may stem from the absence of tumors scored 11–12 and the fact that only 6% of tumors were >7 cm. Third, we have relatively limited follow-up to delineate long-term cancer control. Finally, subtle differences in RARPN technique may contribute to intersurgeon variation in outcomes; however, we describe center-specific differences in the RARPN approach and present a video to reinforce and highlight our approach.

5. Conclusions

RARPN is an effective approach to partial nephrectomy for posterior renal masses with acceptable oncologic outcomes and convalescence. Although there is significant variation in complications and WIT among experienced fellowship-trained surgeons, greater RARPN experience is associated with shorter WIT.

Author contributions: Jim C. Hu had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Hu, Weizer, Porter.
Acquisition of data: Xiong, McLaren, Stepanian.
Analysis and interpretation of data: Hu, Treat, Filson, McLaren, Xiong, Stepanian, Hafez, Porter, Weizer.
Drafting of the manuscript: Hu, Treat, Filson, McLaren, Xiong, Stepanian, Hafez, Porter, Weizer.
Critical revision of the manuscript for important intellectual content: Hu, Treat, Filson, McLaren, Xiong, Stepanian, Hafez, Porter, Weizer.
Statistical analysis: Hu, Xiong.
Obtaining funding: None.
Administrative, technical, or material support: Hu.
Supervision: Hu, Weizer, Porter.
Other (specify): None.

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Appendix A. Supplementary data

The Surgery in Motion video accompanying this article can be found in the online version at http://dx.doi.org/10.1016/j.eururo.2014.04.028 and via www.europeanurology.com.

References

[1] Lee CT, Katz J, Shi W, Thaler HT, Reuter VE, Russo P. Surgical management of renal tumors 4 cm. or less in a contemporary cohort. J Urol 2000;163:730–6.
[2] Hollingsworth JM, Miller DC, Daignault S, Hollenbeck BK. Rising incidence of small renal masses: a need to reassess treatment effect. J Natl Cancer Inst 2006;98:1331–4.
[3] Yu HY, Hevelone ND, Lipsitz SR, Kowalczyk KJ, Hu JC. Use, costs and comparative effectiveness of robotic assisted, laparoscopic and open urological surgery. J Urol 2012;187:1392–8.
[4] Finley DS, Beck S, Box G, et al. Percutaneous and laparoscopic cryoablation of small renal masses. J Urol 2008;180:492–8, discussion 498.
[5] Wright JL, Porter JR. Laparoscopic partial nephrectomy: comparison of transperitoneal and retroperitoneal approaches. J Urol 2005; 174:841–5.
[6] Gaur DD, Agarwal DK, Purohit KC. Retroperitoneal laparoscopic nephrectomy: initial case report. J Urol 1993;149:103–5.
[7] McAllister M, Bhayani SB, Ong A, et al. Vena caval transection during retroperitoneoscopic nephrectomy: report of the complication and review of the literature. J Urol 2004;172:183–5.
[8] Weizer AZ, Palella GV, Montgomery JS, Miller DC, Hafez KS. Robot-assisted retroperitoneal partial nephrectomy: technique and perioperative results. J Endourol 2011;25:553–7.
[9] Patel M, Porter J. Robotic retroperitoneal partial nephrectomy. World J Urol 2013;31:1377–82.
[10] Benway BM, Wang AJ, Cabello JM, Bhayani SB. Robotic partial nephrectomy with sliding-clip renorrhaphy: technique and outcomes. Eur Urol 2009;55:592–9.
[11] Campbell SC, Novick AC, Belldegrun A, et al. Guideline for management of the clinical T1 renal mass. J Urol 2009;182:1271–9.
[12] Canter D, Kutikov A, Manley B, et al. Utility of the R.E.N.A.L. nephrometry scoring system in objectifying treatment decision-making of the enhancing renal mass. Urology 2011;78:1089–94.
[13] Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol 2009;182:844–53.
[14] Ficarra V, Novara G, Secco S, et al. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol 2009;56:786–93.
[15] Kowalczyk KJ, Harbin AC, Choueiri TK, et al. Use of surveillance imaging following treatment of small renal masses. J Urol 2013; 190:1680–5.
[16] Choueiri TK, Schutz FA, Hevelone ND, et al. Thermal ablation vs surgery for localized kidney cancer: a Surveillance, Epidemiology, and End Results (SEER) database analysis. Urology 2011;78: 93–8.
[17] Thompson RH, Lane BR, Lohse CM, et al. Every minute counts when the renal hilum is clamped during partial nephrectomy. Eur Urol 2010;58:340–5.
[18] Hu JC, Gold KF, Pashos CL, Mehta SS, Litwin MS. Role of surgeon volume in radical prostatectomy outcomes. J Clin Oncol 2003;21: 401–5.
[19] Konety BR, Dhawan V, Allareddy V, Joslyn SA. Impact of hospital and surgeon volume on in-hospital mortality from radical cystectomy:

data from the health care utilization project. J Urol 2005;173: 1695–700.
[20] Tan HJ, Wolf Jr JS, Ye Z, Wei JT, Miller DC. Complications and failure to rescue after laparoscopic versus open radical nephrectomy. J Urol 2011;186:1254–60.
[21] Pierorazio PM, Patel HD, Feng T, Yohannan J, Hyams ES, Allaf ME. Robotic-assisted versus traditional laparoscopic partial nephrectomy: comparison of outcomes and evaluation of learning curve. Urology 2011;78:813–9.
[22] Link RE, Bhayani SB, Allaf ME, et al. Exploring the learning curve, pathological outcomes and perioperative morbidity of laparoscopic partial nephrectomy performed for renal mass. J Urol 2005;173: 1690–4.
[23] Mottrie A, De Naeyer G, Schatteman P, Carpentier P, Sangalli M, Ficarra V. Impact of the learning curve on perioperative outcomes in patients who underwent robotic partial nephrectomy for parenchymal renal tumours. Eur Urol 2010;58:127–33.
[24] Kural AR, Atug F, Tufek I, Akpinar H. Robot-assisted partial nephrectomy versus laparoscopic partial nephrectomy: comparison of outcomes. J Endourol 2009;23:1491–7.
[25] Ellison JS, Montgomery JS, Wolf Jr JS, Hafez KS, Miller DC, Weizer AZ. A matched comparison of perioperative outcomes of a single laparoscopic surgeon versus a multisurgeon robot-assisted cohort for partial nephrectomy. J Urol 2012;188:45–50.
[26] Haber GP, White WM, Crouzet S, et al. Robotic versus laparoscopic partial nephrectomy: single-surgeon matched cohort study of 150 patients. Urology 2010;76:754–8.
[27] Jeong W, Park SY, Lorenzo EI, Oh CK, Han WK, Rha KH. Laparoscopic partial nephrectomy versus robot-assisted laparoscopic partial nephrectomy. J Endourol 2009;23:1457–60.
[28] Seo IY, Choi H, Boldbaatr Y, Lee JW, Rim JS. Operative outcomes of robotic partial nephrectomy: a comparison with conventional laparoscopic partial nephrectomy. Korean J Urol 2011;52:279–83.
[29] Williams SB, Kacker R, Alemozaffar M, Francisco IS, Mechaber J, Wagner AA. Robotic partial nephrectomy versus laparoscopic partial nephrectomy: a single laparoscopic trained surgeon's experience in the development of a robotic partial nephrectomy program. World J Urol 2013;31:793–8.
[30] Gill IS, Kavoussi LR, Lane BR, et al. Comparison of 1,800 laparoscopic and open partial nephrectomies for single renal tumors. J Urol 2007; 178:41–6.
[31] Patard J-J, Pantuck AJ, Crepel M, et al. Morbidity and clinical outcome of nephron-sparing surgery in relation to tumour size and indication. Eur Urol 2007;52:148–54.
[32] Marszalek M, Chromecki T, Al-Ali BM, et al. Laparoscopic partial nephrectomy: a matched-pair comparison of the transperitoneal versus the retroperitoneal approach. Urology 2011;77:109–13.
[33] Pyo P, Chen A, Grasso M. Retroperitoneal laparoscopic partial nephrectomy: surgical experience and outcomes. J Urol 2008; 180:1279–83.
[34] Ng CS, Gill IS, Ramani AP, et al. Transperitoneal versus retroperitoneal laparoscopic partial nephrectomy: patient selection and perioperative outcomes. J Urol 2005;174:846–9.
[35] Anast JW, Stoller ML, Meng MV, et al. Differences in complications and outcomes for obese patients undergoing laparoscopic radical, partial or simple nephrectomy. J Urol 2004;172:2287–91.
[36] Naeem N, Petros F, Sukumar S, et al. Robot-assisted partial nephrectomy in obese patients. J Endourol 2011;25:101–5.
[37] Doublet J, Belair G. Retroperitoneal laparoscopic nephrectomy is safe and effective in obese patients: a comparative study of 55 procedures. Urology 2000;56:63–6.
[38] Berglund RK, Gill IS, Babineau D, Desai M, Kaouk JH. A prospective comparison of transperitoneal and retroperitoneal laparoscopic nephrectomy in the extremely obese patient. BJU Int 2007;99: 871–4.
[39] Elsamra SE, Leone AR, Lasser MS, et al. Hand-assisted laparoscopic versus robot-assisted laparoscopic partial nephrectomy: comparison of short-term outcomes and cost. J Endourol 2013;27:182–8.
[40] Hughes-Hallett A, Patki P, Patel N, Barber NJ, Sullivan M, Thilagarajah R. Robot-assisted partial nephrectomy: a comparison of the transperitoneal and retroperitoneal approaches. J Endourol 2013; 27: 869–74.

Multi-Institutional Experience with Robotic Nephrectomy with Inferior Vena Cava Tumor Thrombectomy

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Purpose: Since the first report of robotic management of renal tumors with inferior vena cava tumor thrombi, few additional cases have been reported in the literature. We report our combined experience with this procedure, to our knowledge the first multi-institutional and largest series reported to date.

Materials and Methods: A retrospective, multi-institutional review of robotic nephrectomy with inferior vena cava tumor thrombectomy was performed with institutional review board approval.

Results: A total of 32 cases were performed among 9 surgeons at 9 institutions since the first known procedure in 2008. Of these cases 30 were level II and 2 were level III thrombi with no level I thrombi (renal vein only) included in the analysis. Each surgeon performed between 1 and 10 procedures. Mean patient age was 63 years (range 43 to 81) with a mean body mass index of 30 kg/m^2 (range 17 to 43) and mean maximal tumor diameter of 9.6 cm (range 5.4 to 20). The length of inferior vena cava tumor thrombi ranged from 1 to 11 cm (median 4.2) on preoperative imaging. The inferior vena cava required cross-clamping in 24 cases. One patient had 2 renal veins with 2 caval thrombi and 1 patient required synthetic patch cavoplasty. Mean operative time was 292 minutes (range 180 to 411) with a mean blood loss of 399 cc (range 25 to 2,000). There were no conversions to open surgery or aborted procedures and there were 3 transfusions of 1 to 3 units. All but 2 patients ambulated by postoperative day 1 and mean hospital stay was 3.2 days (range 1 to 7). Lymphadenectomy in 24 patients yielded a mean of 11 nodes and 8 patients had node positive disease. There were 7 patients who experienced distant recurrence at a mean followup of 15.4 months, including 4 who had node positive disease on postoperative pathological examination.

Conclusions: Robotic nephrectomy in the setting of inferior vena cava tumor thrombus is feasible and was performed safely in selected patients. Despite the complex and critical nature of these procedures, our series demonstrates favorable outcomes and reproducibility with adequate robotic experience.

Key Words: robotics; laparoscopy; nephrectomy; carcinoma, renal cell; vena cava, inferior

Abbreviations and Acronyms

IVC = inferior vena cava

RCC = renal cell carcinoma

RNIT = robotic nephrectomy with IVC thrombectomy

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Renal cell carcinoma can involve tumor thrombus into the renal vein or the inferior vena cava in 4% to 36% of cases.[1] While renal vein tumor thrombus can often be managed in a minimally invasive fashion, open surgery remains the standard surgical treatment for IVC thrombus as laparoscopy is considered contraindicated for this condition by most experts.[1–3]

The complexity of the operation and potentially fatal complications that can occur in the course of tumor thrombectomy and IVC reconstruction have limited the application of laparoscopy.[4] Minimally invasive nephrectomy for IVC thrombus requiring cross-clamping of the cava had not been reported until the first such robotic series published in 2011.[5] Before this time laparoscopy had only been used for short thrombi not requiring IVC clamping or before an open incision to manage the IVC.[6]

Since then, only 1 laparoscopic series[7] and individual cases or videos of robotic nephrectomy for RCC with IVC thrombi have been published.[8–12] The safety and reproducibility of minimally invasive surgery for such complex tumors remain uncertain due to the scarcity of cases reported. We report the first multi-institutional and the largest series to date to our knowledge of robotic nephrectomy with IVC thrombectomy.

METHODS

A multi-institutional database of RNIT procedures at 9 institutions was compiled with institutional review board approval and inter-institutional data sharing agreements as required. Each institution collected data prospectively while compilation of the data among institutions was done retrospectively in a de-identified fashion. Procedures were performed between 2008 and 2014. All patients who underwent RNIT at these institutions were elicited regardless of whether the procedure was completed robotically or whether open conversion was necessary. Given the retrospective nature of the study, inclusion criteria were at the discretion of the operating surgeon and were not uniform.

Demographic and perioperative data were reviewed, including patient age, gender, body mass index, operative time, estimated blood loss, conversion rate, transfusion requirements, tumor histology and stage, thrombus length, margin status, nodal status, length of stay, complications and cancer recurrence. Due to the small number of patients, descriptive statistics only were analyzed (eg medians, means etc).

RESULTS

A total of 32 cases were performed among 9 surgeons at 9 institutions since the first known procedure in 2008, with each surgeon having performed between 1 and 10 RNIT procedures. Among the 9 surgeons previous robotic surgery experience before performing RNIT averaged 1,100 robotic cases (range 600 to 2,500).

Right side tumors accounted for 27 of the 32 procedures. All patients underwent preoperative cross-sectional imaging with computerized tomography or magnetic resonance imaging and 1 surgeon performed a vena cavogram before his first procedure (fig. 1). Mean patient age was 63 years (range 43 to 81) and mean body mass index was 30 kg/m^2 (range 17 to 43). Overall 30 IVC thrombi were level II (below hepatic veins) and 2 were level III (above hepatic veins but below diaphragm) according to the Novick classification with no level I thrombi (renal vein only) included in the series. The maximal tumor diameter was 9.6 cm (range 5.4 to 20) with IVC tumor thrombus length ranging from 1 to 11 cm (median 4.2) on preoperative imaging. No patient underwent preoperative renal artery angioembolization.

There were no conversions to open surgery or aborted procedures. Among the 24 (75%) procedures with tumor thrombus length requiring cross-clamping of the IVC, clamping was performed with bulldog clamps or modified Rommel tourniquets using vessel loops. Shorter IVC thrombi were managed with tangential clamping of the IVC using a laparoscopic Satinsky clamp. Procedures were performed using a maximum of 8 port sites (4 assistant ports) to as few as 3 ports with a stab incision for the Satinsky clamp in less complex procedures (no assistant port).

All procedures were performed transperitoneally as previously described with minor variations among surgeons.[5] Cross-clamping of the IVC was accomplished after ligating the arterial supply and circumferentially dissecting the cava above and below the thrombus, placing modified Rommel tourniquets in the form of vessel loops doubly wrapped around

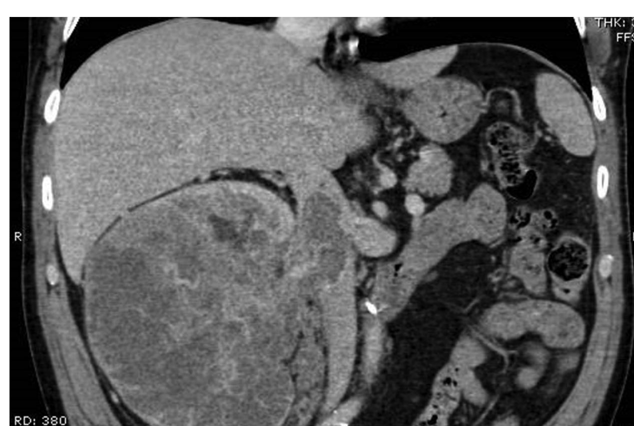

Figure 1. Representative preoperative computerized tomography of 20 cm primary right renal mass with level II IVC thrombus.

the IVC (fig. 2). Alternatively some surgeons selectively used bulldog clamps to replace 1 or more tourniquets. The left renal vein was controlled in a similar fashion, and all lumbar veins were clipped and divided or controlled with bipolar cautery when small (fig. 3). The cava was only opened once all inflow was controlled or clamped by cinching the vessel loops so that a bloodless field was maintained during thrombus extraction (fig. 4). The cava was suture reconstructed and flushed with heparinized saline before releasing tourniquets to reestablish blood flow (fig. 5).

Left side tumor thrombi were managed completely in the left flank position in 4 patients with short thrombi where adequate access to the IVC was possible without repositioning and 3 were managed with tangential IVC clamping only. One patient required repositioning from right flank for IVC management and tumor thrombus extraction to left flank position to complete the nephrectomy. In all procedures regardless of side the tumor thrombus was removed en bloc with the kidney and tumor. Level III intrahepatic, infradiaphragmatic thrombi required division of the short hepatic veins to allow control of the IVC above the thrombus (fig. 2). In these cases the short hepatic veins were clipped and divided before using laparoscopic ultrasound to identify the cranial-most extent of the tumor for placement of the tourniquet.

The mean operative time from incision to closure including console time was 292 minutes (range 180 to 411). Mean blood loss was 399 cc (range 25 to 2,000) with 3 patients (9%) receiving transfusions of 1 to 3 units of packed red blood cells. A closed suction drain was left in 2 cases. One patient had extensive tumor infiltration into the vena cava wall requiring wide excision and vena cavoplasty with a Dacron® patch. One patient had 2 renal veins, each with a caval thrombus, and 1 patient had a caval thrombus in the renal vein as well as 1 extending into the cava through the adrenal vein. The length of extraction incisions was recorded in only 15 patients and varied from 4 to 14 cm depending on the size of the specimen and patient body habitus.

Robotic retroperitoneal lymphadenectomy was performed in 24 patients. Mean lymph node yield was 11 (range 1 to 25) and 8 patients had involved nodes (range 1 to 20 positive nodes, median 3). Six tumors had sarcomatoid histology involving 5% to 90% of the tumor volume. Three tumors were Fuhrman grade II and all others were grade III or IV. Excluding the exposed IVC tumor thrombus 2 patients (6%) had positive surgical margins, including in 1 pT4 tumor.

Intraoperative complications occurred in only 1 patient who had a bowel injury during access that was repaired primarily. Postoperative complications occurred in 7 other patients, and included shortness of breath requiring Lasix (Clavien I), pneumonia, pulmonary embolism, ileus and emergency room visit for cardiac complaints in 1 patient each, as well as temporary renal impairment not requiring dialysis in 2 patients (Clavien II). No patients experienced Clavien III-V complications.

Ambulation on the day of surgery or by postoperative day 1 was achieved by 30 of the 32

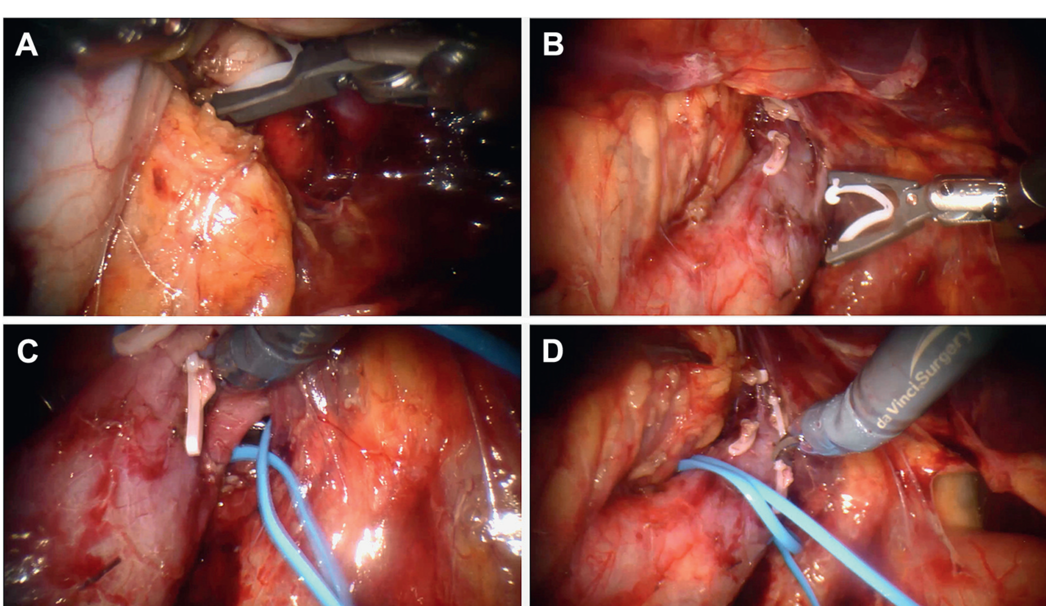

Figure 2. Interaortocaval clipping of right renal artery (*A*) followed by clipping and division of short hepatic veins (*B*) for maximal cranial control of IVC for placement of vessel loop just below liver edge (*C*) and repeated to encircle cava (*D*).

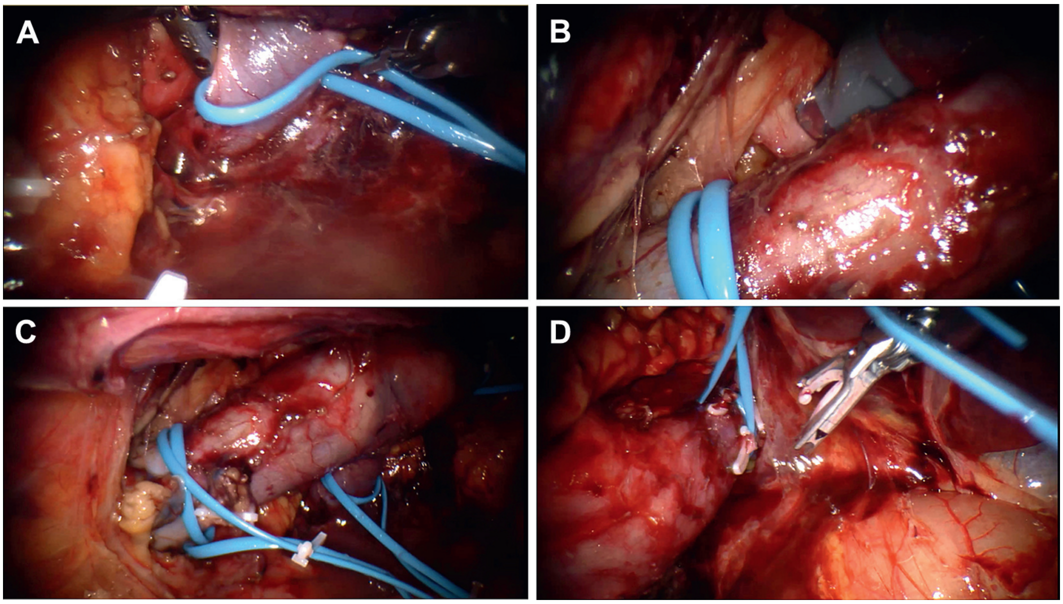

Figure 3. Modified Rommel tourniquet placed around left renal vein (*A*) and dissection of all lumbar vessels (*B*) as well as control of caudal IVC (*C*) before cinching tourniquets and placing clip to initiate complete IVC clamping (*D*).

patients. Intravenous narcotics were not needed for pain control in 24 patients (75%) during the postoperative period after leaving the recovery room until discharge home, while 8 patients did receive intravenous narcotics. Resumption of regular diet occurred on average on postoperative day 1.1 (range 0 to 4) with 21 patients on regular diets by postoperative day 1. Median hospital stay was 3 days (mean 3.2, range 1 to 7) with 22 patients (69%) discharged home on or before postoperative day 3.

One patient had known metastatic disease at surgery and underwent cytoreductive RNIT, and 4 others had suspected metastasis in the form of retroperitoneal lymphadenopathy on preoperative imaging. Mean followup was 15 months (range 1 to 50). There were no 90-day mortalities. Adjuvant systemic therapy was not used in patients with no evidence of disease postoperatively. There were 7 patients who experienced distant recurrence, of whom 3 died of the disease. Of these 7 patients 4

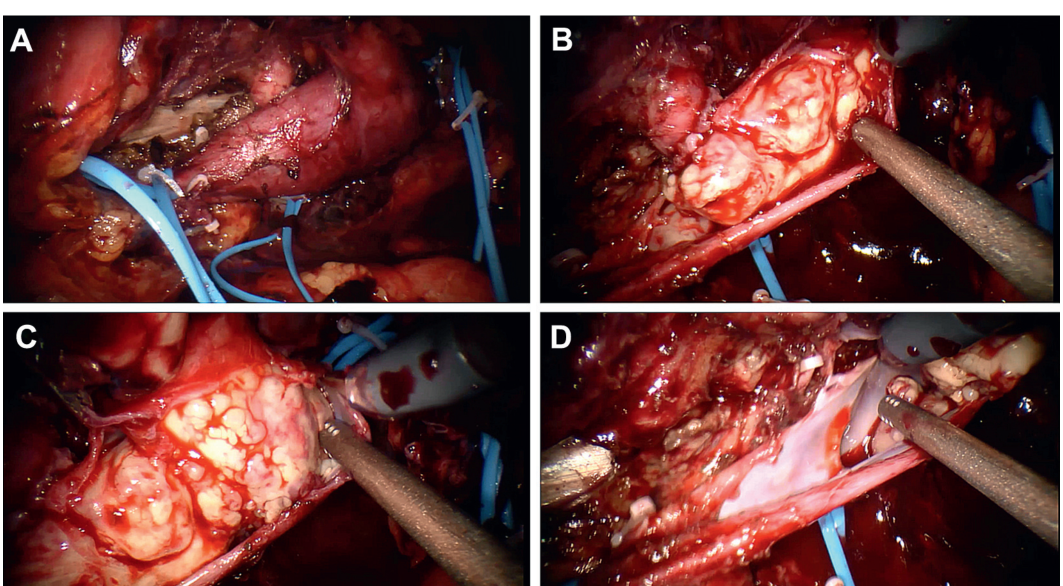

Figure 4. Completely clamped IVC with all 3 tourniquets cinched (*A*) before incision of IVC under complete hemostatic control (*B*), and visualizing upper extent of tumor thrombus (*C*) and os of left renal vein (*D*).

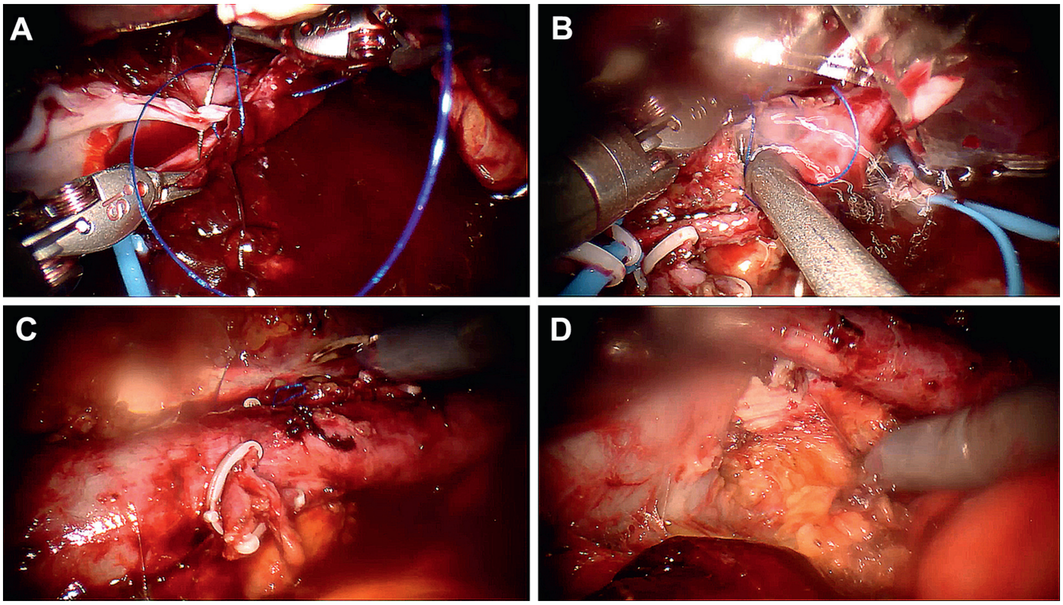

Figure 5. Sutured reconstruction of IVC (*A*) with flush using heparinized saline through laparoscopic suction irrigator (*B*) before completing IVC closure (*C*) followed by node dissection including anterior retraction of already mobilized IVC to access retrocaval nodes (*D*).

had positive lymph nodes identified on postoperative pathological examination.

DISCUSSION

Since the introduction of laparoscopic nephrectomy, this minimally invasive procedure has demonstrated benefits compared to open surgery that include reduced blood loss and pain, and shorter hospitalization and recovery time. These findings have persisted even as laparoscopy has been applied to increasingly large and more complex tumors.[13,14] Nephrectomy for tumors with IVC thrombi is among the most challenging scenario in RCC. However, the ability to manage such tumors in a minimally invasive fashion could confer a significant advantage to patients if it can be performed safely and reproducibly.

The first attempt at minimally invasive management of an IVC tumor thrombus was reported in 2002 when hand assisted laparoscopy was used for a short thrombus that could be excluded from the cava by a Satinsky clamp.[15] Porcine and bovine models for larger laparoscopic IVC tumor thrombectomy were developed in 2002 and 2003.[16,17] Pure laparoscopy in a human patient was reported in 2006, again for a short thrombus not requiring IVC cross-clamping.[18]

Completely intracorporeal management of larger IVC thrombi requiring IVC cross-clamping was not reported until the first successful procedures were completed in robotic fashion.[5] Since then, pure laparoscopic procedures duplicating the technique have been successfully performed in China.[7] Whether pure laparoscopic management can be widely replicated by other groups remains to be seen, but our series indicated that the robotic technique is feasible among experienced robotic surgeons with some limitations that continue to be explored. Several groups are working on adjustments to allow even more extensive caval thrombi to be managed robotically,[9] and it is likely only a matter of time before complex variations are no longer considered obstacles, such as circumcaval caudate lobes of the liver, accessory hepatic veins or invasion of the caval wall, among others.

While our series supports a role for robotics in the minimally invasive management of IVC tumor thrombi, open surgery remains the standard therapy. It should also be emphasized that the robotic surgeons who embarked on this procedure did so after extensive experience with other robotic procedures, including kidney surgery. Given the complexity of the procedure and potential major intraoperative complications, including death, the procedure should be approached cautiously. Also, surgeons should have a low threshold for conversion to open surgery if thrombus length or oncologic principles are in question, and the surgeon and team should be prepared for the potential need for open surgery. In addition, the fact that no open conversions occurred in this series and that the 9 surgeons represented had no such cases during this period likely reflect not only surgeon preparation and experience before attempting RNIT but also equally or potentially more judicious patient selection.

Particular attention should be paid to the size and length of tumor thrombi attempted robotically. Even experienced surgeons are encouraged to begin their approach to IVC thrombi with shorter thrombi requiring less extensive mobilization of the IVC, with the eventual ability to manage level III thrombi robotically. Control of the suprahepatic, infradiaphragmatic IVC was not performed in this series as it was not necessitated by the length of thrombi, but even this step has recently been described in a cadaver model robotically.[19] Also, 2 groups separate from our multi-institutional cohort recently described a case report and small series of specifically level III robotic thrombus management, further indicating the potential for future evolution and adoption.[20,21]

Our study was limited by a lack of inclusion criteria such that patient selection was not standardized across sites. The mean tumor size of 9.6 cm compares similarly with historical open series of RCC with IVC thrombi including 109 such patients reported by Kim et al who had a mean tumor size of 10.3 cm[22] and 49 patients (7 renal vein thrombi) reported by Parekh et al with a median tumor size of 10 cm.[23] This suggests that primary tumor size may not have been a selection factor, particularly since our range included tumors as large as 20 cm. With only 2 level III thrombi in our series, the uppermost extension of the thrombus may have been a selection criterion for surgeons, which is reasonable and reflects a likely preference for beginning with shorter thrombi. Surgeons should also be prepared for the possibility of caval wall invasion, which can occur in approximately 3% of caval thrombi and requires patch or graft reconstruction as in 1 of our cases.[24]

The benefits of minimally invasive surgical management of any condition are mostly short-term. Oncologic control remains a priority over the temporary benefits of avoiding large, open incisions. The oncologic outcomes observed in our series compare well with historical series given that the 5-year disease specific survival for nonmetastatic RCC with IVC thrombus is only 40% to 65%, and is only 6% to 28% for those presenting with metastasis.[1] While recurrences in 7 of 32 patients (22%) with a mean followup of only 15 months may initially seem high to those unfamiliar with T3b RCC, such a rate is not unexpected for T3b RCC and does not suggest an unfavorable oncologic impact of performing these surgeries minimally invasively.

In 111 patients undergoing open surgery for RCC with IVC thrombus with a median followup of 16.8 months Haferkamp et al reported recurrence in 54% of patients, even among those without metastatic disease.[25] In addition, several cytoreductive nephrectomies were performed in our patients with known or suspected metastatic disease. Still, longer term followup will be necessary to confirm the ability of the robotic approach to duplicate historical open oncologic results and to determine whether the selection criteria for a robotic approach in these cases may have favorably biased oncologic outcomes.

If oncologic outcomes can be confirmed, the true benefit of a minimally invasive approach would be in the potential to reduce convalescence and complications. Due to the complexity of the condition and the operation, the complication rate with open surgery is 12% to 47%, depending on the thrombus level, with a mortality rate of 5% to 10%.[26] Our complication rate and lack of mortalities compare reasonably with open series with no Clavien III-V complications in any patient, including no deaths. While complications were relatively minor in our series, it is evident that complications are not entirely avoidable. Even with a minimally invasive approach, the surgical management of severe cancers in mostly elderly patients will likely involve complications, although the type may vary as with other open procedures that have transitioned to less invasive surgery.

Further experience with RNIT, performed in more patients and by additional surgeons, will be necessary to clarify whether the benefits of other minimally invasive surgeries like reduced blood loss, pain and hospitalization apply to this complex procedure and patient population. In addition, future studies comparing matched patient populations undergoing open surgery vs RNIT will be beneficial as more patients undergoing RNIT become available. While our study suggests reproducibility among experienced robotic surgeons, this initial experience likely represents a carefully selected group of patients such that extension of this series and others will allow additional definition of the potential role for RNIT.

CONCLUSIONS

RNIT is a feasible and reproducible procedure for the management of RCC with IVC tumor thrombus by experienced robotic surgeons. Continued exploration will help identify ideal candidates for RNIT and possible exclusions as well as confirm the potential benefits of a completely intracorporeal approach to these tumors.

ADDENDUM

Subsequent to our study, one of our surgeons performed RNIT on a patient who died of respiratory failure postoperatively, reflecting the complex and serious nature of these surgeries.

REFERENCES

1. Pouliot F, Shuch B, LaRochelle JC et al: Contemporary management of renal tumors with venous tumor thrombus. J Urol 2010; **184:** 833.
2. Novick AC: Laparoscopic and partial nephrectomy. Clin Cancer Res, suppl., 2004; **10:** 6322S.
3. Eisenberg MS, Meng MV, Master VA et al: Laparoscopic versus open cytoreductive nephrectomy in advanced renal-cell carcinoma. J Endourol 2006; **20:** 504.
4. Bharti N and Kumar L: Fatal pulmonary embolism by tumour thrombus during surgery for renal cell carcinoma. J Anaesthesiol Clin Pharmacol 2007; **23:** 311.
5. Abaza R: Initial series of robotic radical nephrectomy with vena caval tumor thrombectomy. Eur Urol 2011; **59:** 652.
6. Abaza R: Robotic surgery and minimally invasive management of renal tumors with vena caval extension. Curr Opin Urol 2011; **21:** 104.
7. Shao P, Li J, Qin C et al: Laparoscopic radical nephrectomy and inferior vena cava thrombectomy in the treatment of renal cell carcinoma. Eur Urol 2015; **68:** 115.
8. Lee JY and Mucksavage P: Robotic radical nephrectomy with vena caval tumor thrombectomy: experience of novice robotic surgeons. Korean J Urol 2012; **53:** 879.
9. Sun Y, Abreu AL and Gill IS: Robotic inferior vena cava thrombus surgery: novel strategies. Curr Opin Urol 2014; **24:** 140.
10. Lee Z, Reilly CE, Parkes L et al: Robotic right nephrectomy and inferior vena cava tumor thrombectomy with caval patch graft reconstruction. J Endourol Part B, Videourology 2013; Epub ahead of print.
11. Grimsby GM, Stone WM and Castle EP: Robot-assisted radical nephrectomy and inferior vena cava tumor thrombectomy. J Endourol Part B, Videourology 2013; 27.
12. Mendoza PJ, Steixner B, Schwab CW et al: Robotic right radical nephrectomy with inferior vena cava tumor thrombectomy. J Endourol, suppl., 2010; **24:** A244, abstract PS30—25.
13. Fenn NJ and Gill IS: The expanding indications for laparoscopic radical nephrectomy. BJU Int 2004; **94:** 761.
14. Hemal AK, Kumar A, Kumar R et al: Laparoscopic versus open radical nephrectomy for large renal tumors: a long-term prospective comparison. J Urol 2007; **177:** 862.
15. Sundaram CP, Rehman J, Landman J et al: Hand assisted laparoscopic radical nephrectomy for renal cell carcinoma with inferior vena caval thrombus. J Urol 2002; **168:** 176.
16. Fergany AF, Gill IS, Schweizer DK et al: Laparoscopic radical nephrectomy with level II vena caval thrombectomy: survival porcine model. J Urol 2002; **168:** 2629.
17. Meraney AM, Gill IS, Desai MM et al: Laparoscopic inferior vena cava and right atrial thrombectomy utilizing deep hypothermic circulatory arrest. J Endourol 2003; **17:** 275.
18. Romero FR, Muntener M, Bagga HS et al: Pure laparoscopic radical nephrectomy with level II vena caval thrombectomy. Urology 2006; **68:** 1112.
19. Abreu AL, Chopra S, Azhar RA et al: Robotic transabdominal control of the suprahepatic, infradiaphragmatic vena cava to enable level 3 caval tumor thrombectomy: pilot study in a perfused-cadaver model. J Endourol 2015; **29:** 1177.
20. Bratslavsky G and Cheng JS: Robotic assisted radical nephrectomy with retrohepatic vena caval tumor thrombectomy (level III) combined with extended retroperitoneal lymph node dissection. Urology 2015; Epub ahead of print.
21. Gill IS, Metcalfe C, Abreu A et al: Robotic level III inferior vena cava tumor thrombectomy: initial series. J Urol 2015; **194:** 929.
22. Kim HL, Zisman A, Han KR et al: Prognostic significance of venous thrombus in renal cell carcinoma. Are renal vein and inferior vena cava involvement different? J Urol 2004; **171:** 588.
23. Parekh DJ, Cookson MS, Chapman W et al: Renal cell carcinoma with renal vein and inferior vena cava involvement: clinicopathological features, surgical techniques and outcomes. J Urol 2005; **173:** 1897.
24. Moinzadeh A and Libertino JA: Prognostic significance of tumor thrombus level in patients with renal cell carcinoma and venous tumor thrombus extension. Is all T3b the same? J Urol 2004; **171:** 598.
25. Haferkamp A, Bastian PJ, Jakobi H et al: Renal cell carcinoma with tumor thrombus extension into the vena cava: prospective long-term followup. J Urol 2007; **177:** 1703.
26. Lawindy SM, Kurian T, Kim T et al: Important surgical considerations in the management of renal cell carcinoma (RCC) with inferior vena cava (IVC) tumour thrombus. BJU Int 2012; **110:** 926.

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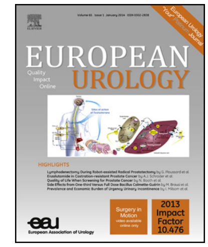

European Association of Urology

Renal Disease

Determinants of Laparoscopic Donor Nephrectomy Outcomes

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Abstract

Background: Pure laparoscopic donor nephrectomy (LDN) is a unique intervention because it carries known risks and complications, yet carries no direct benefit to the donor. Therefore, it is critical to continually examine and improve quality of care.
Objective: To identify factors affecting LDN outcomes and complications.
Design, setting, and participants: A retrospective analysis of prospectively collected data for 1204 consecutive LDNs performed from March 2000 through August 2012.
Intervention: LDN performed at an academic training center.
Outcome measurements and statistical analysis: Using multivariable regression, we assessed the effect of age, sex, body mass index (BMI), laterality, and vascular variation on operative time, estimated blood loss (EBL), complications, and length of stay.
Results and limitations: The following variables were associated with longer operative time (data given as parameter estimate plus or minus the standard error): female sex (9.09 ± 2.43; $p < 0.001$), higher BMI (1.03 ± 0.32; $p = 0.001$), two (7.87 ± 2.70; $p = 0.004$) and three or more (22.45 ± 7.13; $p = 0.002$) versus one renal artery, and early renal arterial branching (5.67 ± 2.82; $p = 0.045$), while early renal arterial branching (7.81 ± 3.85; $p = 0.043$) was associated with higher EBL. Overall, 8.2% of LDNs experienced complications, and by modified Clavien classification, 74 (5.9%) were grade 1, 13 (1.1%) were grade 2a, 10 (0.8%) were grade 2b, and 2 (0.2%) were grade 2c. There were no grade 3 or 4 complications. Three or more renal arteries (odds ratio [OR]: 2.74; 95% CI, 1.05–7.16; $p = 0.04$) and late renal vein confluence (OR: 2.42; 95% CI, 1.50–3.91; $p = 0.0003$) were associated with more complications. Finally, we did not find an association of the independent variables with length of stay. A limitation is that warm ischemia time was not assessed.
Conclusions: In our series, renal vascular variation prolonged operative time and was associated with more complications. While complicated donor anatomy is not a contraindication of LDN, surgical decision-making should take into consideration these results.

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1. Introduction

Living donor versus deceased donor kidney transplantation is associated with better outcomes [1]. Improved graft survival at 1 yr and 10 yr has been achieved with living donor transplantation. This improvement is thought to arise from decreased ischemia times, selection of healthy donors, and shortened waiting times for transplantation with living donor approaches [2–4]. Furthermore, with new matching strategies such as donor chains and paired exchanges,

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improved outcomes may be seen from enhanced donor–recipient matching [5].

The laparoscopic approach has become the optimal approach for living donor nephrectomy, due to less postoperative pain, quicker convalescence, decreased morbidity, and improved cosmetic appearance compared to the traditional open approach [6]. Several distinct surgical approaches to living donor nephrectomy have developed in the laparoscopic era, including, pure laparoscopic donor nephrectomy (LDN), hand-assisted LDN, minilaparoscopy, retroperitoneal and transperitoneal approaches, and more recently, laparoendoscopic single-site, and robotic donor nephrectomy. Currently, LDN, hand-assisted LDN, and open donor nephrectomy make up the majority of procedures performed [7,8].

LDN is a unique operation in that it is an elective operation performed on healthy individuals; therefore, every effort must be made to attenuate perioperative morbidity and ensure a rapid return to baseline. This study aims to investigate donor characteristics effects on donor outcomes (operative time, estimated blood loss [EBL], complications, and length of stay [LOS]) to identify potential areas for improvement.

2. Methods

2.1. Enrollment and selection criteria

From March 2000 through August 2012, 1204 consecutive LDNs were performed at an academic training center, and patient characteristics and outcomes were prospectively entered into a University of California Los Angeles (UCLA) institutional review board-approved Access database (Microsoft, Redmond, WA, USA). Selection of potential donors to undergo surgery was made after a rigorous evaluation by a nephrologist, a surgeon, a psychiatrist, and an independent donor advocate. Routine evaluation included the following laboratory tests: urine analysis and culture, 24-h urine collection to measure protein and creatinine levels to estimate glomerular filtration rate, complete blood count, chemistry panel, pregnancy testing, and appropriate serologies for donation (hepatitis, human immunodeficiency virus, cytomegalovirus, Epstein-Barr virus, and herpes simplex virus) and cross matching. Every candidate received a multidetector, triple phase, contrast computed tomography (CT) scan with urogram. Of the 1162 subjects with complete record of CT findings, the intraoperative findings of 1139 (98%) subjects were consistent with that of the CT imaging. No nuclear studies were performed. Voiding cystourethrogram or other studies were seldom done and only as indicated by patient history or findings on routine labs and CT imaging. Donor selection was finalized by a multidisciplinary donor-selection committee. The donors were healthy donors with Charlson Comorbidity Index score of 0 in all cases, and the left kidney was preferentially selected to provide longer vein length during transplantation. Additionally, longer left renal vein length was preferred even in the presence of up to two left renal arteries.

2.2. Surgical technique

Our technique for LDN has been previously described [9,10]. Four different surgeons fellowship trained in laparoscopy (PGS, JCH, AE) or transplantation (HAG) performed the surgery in our series. Briefly, patients are placed in the lateral decubitus position and LDN is performed via a transperitoneal approach. A Veress needle is used for insufflation and three 5-mm trocars are placed along the rectus margin beneath the costal margin. Another 5-mm port is placed in the anterior axillary line under the costal margin to aid lateral hilar retraction. A Pfannestiel incision allows the insertion of a 15-mm trocar to accommodate: (1) the endovascular stapler (Multifire Endo GIA 30; Covidien, Dublin, Ireland) for renal hilar ligation and division; (2) a Hem-o-Loc (Weck Closure Systems, Research Triangle Park, NC, USA) clip applier for ligation of the ureter at the level of common iliac artery; and (3) a laparoscopic bag for specimen retrieval. Mannitol (7.5 mg) is administered at the time of Veress needle insertion and again just prior to specimen retrieval. Subcutaneous bupivacaine and intravenous ketorolac are used for postoperative analgesia, in addition to narcotics on an as-needed basis.

2.3. Statistical analysis

2.3.1. Independent variables

Patient characteristics included age, sex, body mass index (BMI), laterality, and vascular anatomic variation. Vascular anatomic variation included multiple renal arteries and veins, early renal artery branching (within 2 cm of the aorta for left-side donors and proximal to the right wall of the inferior vena cava for right-side donors), and late renal vein confluence (left renal vein branch convergence within 1.5 cm of the aorta and right renal vein branch convergence within 1.5 cm of the inferior vena cava).

2.3.2. Dependent variables

Operative time was defined as the interim between Veress needle insertion and completion of skin closure. Other dependent variables included EBL, LOS, and complications as defined by the modified Clavien classification [11].

For univariable analysis, we used the Wilcoxon rank-sum test for nonparametric variable comparison, *t* test for continuous variable comparison, and chi-square test for categorical variable comparison. For multivariable analyses, we selected covariables a priori in our linear (continuous outcomes: operative time, EBL, and LOS) and logistic regression (complications) that may have influenced our outcomes of interest. Additionally, we performed additional multivariable regression analyses for clinical interpretability to examine factors associated with EBL $\geq$50 ml versus $<$50 ml and complications that were self limited (Clavien 1 and 2a) versus those requiring intervention (Clavien 2b, 2c) versus no complication.

3. Results

3.1. Study population characteristics

The demographic and clinical characteristics of the study cohort are reported in Table 1. The mean age and BMI were 41.2 yr (range: 18–70 yr) and 25.8 kg/m^2(range: 14–37 kg/m^2), respectively. Among 1204 LDNs, the left kidney was removed in 1187 (98.6%) of the cases. Male patients accounted for 481 (40%) of the cases. Renal vascular variation occurred in 674 (55.98%) of donors and 278 (23.9%) donors had two renal arteries. Early renal arterial branching occurred in 249 (20.8%) donors. Late renal vein confluence was found in 230 (19.3%) cases. Overall, there were 99 (8.2%) complications, including 3 (0.3%) open conversions, 55 (4.6%) postoperative emergency room visits, and 16 (1.4%) hospital readmissions (Table 2). One (0.08%) patient required a blood transfusion. Open conversions were for an iliac injury with Veress needle, stapler misfire, and the last was for failure to progress.

Table 1 – Characteristics of the study population and operation (n = 1204)

Variable	Result
Age, yr, mean ± SD	41.2 ± 11.1
Body mass index, kg/m^2, mean ± SD	25 ± 3.7
Operative time, min, mean ± SD	211.5 ± 34.7
Estimated blood loss, ml, mean ± SD	39.8 ± 50.9
Length of stay, d, mean ± SD	1.4 ± 0.7
Sex, no. (%)	
Male	723 (60.1)
Female	481 (40.0)
Side, no. (%)	
Right	17 (1.4)
Left	1187 (98.6)
Number of renal arteries, no. (%)	
1	887 (74.2)
2	278 (23.3)
3	27 (2.3)
4	3 (0.3)
Early renal artery branch, no. (%)	249 (20.8)
Number of renal veins, no. (%)	
1	1139 (95.2)
2	53 (4.4)
3	4 (0.3)
Late confluence of renal vein, no. (%)	230 (19.3)

Table 2 – Overall complications by Clavien classification (n = 99; 8.2%)

Clavien*	Description	No.	%
1		74	5.9
	Wound infection	17	
	Seroma	15	
	Hematoma	10	
	Pain, scrotal	7	
	Acute urinary retention	4	
	Dermatitis	4	
	Constipation	3	
	Pain, unspecified	3	
	Pneumothorax	2	
	Nausea/vomiting	2	
	Vertigo	1	
	Urinary tract infection	1	
	Acute renal injury	1	
	Numbness-face	1	
	Pleural effusion	1	
	Pain, incisional	1	
	Diarrhea	1	
2a		13	1.1
	Nausea/vomiting	3	
	Acute renal injury	1	
	Urinary tract infection	1	
	Pain, nose	1	
	Deep vein thrombosis	1	
	Pain, abdominal	1	
	Fever of unknown origin	1	
	Ileus	1	
	Lower extremity swelling (not DVT)	1	
	Shortness of breath	1	
	Aspiration pneumonia	1	
	Urticaria	1	
2b		10	0.8
	Incisional hernia	3	
	Hematoma	2	
	Chylous ascities	1	
	Internal hernia	1	
	Appendicitis	1	
	Reintubation, airway obstruction	1	
	Postoperative bleeding	1	
2c		2	0.2
	Varess injury to iliac artery	1	
	Stapler misfire	1	

DVT = deep vein thrombosis.
* There were no Clavien 3 or 4 complications.

Unadjusted outcomes stratified by independent variables of interest are reported in Table 3. The univariable analyses showed female sex ($p < 0.001$), greater BMI ($p < 0.001$), two and three or more renal arteries ($p < 0.001$), and early renal artery branching ($p = 0.002$) were significantly associated with longer operative time. There was no significant difference in complications between right-sided and left-sided LDN. Having multiple renal arteries was associated with more complications ($p = 0.014$), particularly three or more (20% vs 8.7%). Late renal vein confluence versus no late confluence was also associated with more complications (7.4% vs 4.1%, respectively; $p = 0.031$). Female patients experienced longer hospital stays than male patients (1.5 vs 1.4 d, respectively; $p = 0.037$).

Adjusted analyses for factors associated with operative time, EBL, complications, and LOS are shown in Table 4. Longer operative time was associated with the following (all data given as parameter estimate plus or minus standard error): female sex (9.09 ± 2.43; $p < 0.001$), higher BMI (1.03 ± 0.11; $p = 0.001$), two renal arteries (7.87 ± 2.70; $p = 0.004$), and three or more renal arteries (22.45 ± 7.17; $p = 0.002$) versus one renal artery, and early renal arterial branching (5.67 ± 2.82; $p = 0.045$). Additionally, early renal arterial branching (7.81 ± 7.81; $p = 0.043$) was associated with higher EBL. Factors associated with more complications included three or more versus one renal artery (odds ratio [OR]: 2.74; 95% confidence interval [CI], 1.05–7.16; $p = 0.04$) and late renal vein confluence (OR: 2.42; 95% CI, 1.50–3.91; $p < 0.001$).

Using logistic regression to assess factors associated with EBL, when dichotomizing to ≥50 ml versus < 50 ml, we did not find identify statistically significant covariables. Similarly, we did not identify covariables associated with complications that required intervention (Clavien grade 2b, 2c). Finally, we did not identify any factors associated with prolonged LOS.

4. Discussion

LDN has been widely adopted since its introduction in 1995 [12], and has advantages of improved postoperative pain and shorter convalescence compared to the open approach. However, regardless of approach, the main goal of the surgery remains minimizing harm to the donor, and our study was conducted to examine factors associated with improving quality in our outcomes of interest. Our study has several important findings. First, multiple renal arteries, higher BMI, early arterial branching, and female sex were associated with longer operative times. Genc et al. reported that mean operative times were longer for two and three versus one renal artery [13]. Additionally, Heimbach et al. demonstrated that higher BMI was associated with longer

Table 3 – Laparoscopic donor nephrectomy operative time, blood loss, complications, and length of stay

	Operative time		Estimated blood loss		Complications		Length of stay	
	Mean ± SD	*p*	Mean ± SD	*p*	No. (%)	*p*	Mean ± SD	*p*
Age, yr								
<40	211.3 ± 33.4	0.977	41.5 ± 68.0	0.512	48 (8.1)	0.991	1.5 ± 0.8	0.214
40–60	211.7 ± 36.6		38.0 ± 24.2		45 (8.1)		1.4 ± 0.6	
>60	211.0 ± 28.9		39.1 ± 32.5		5 (8.6)		1.3 ± 0.6	
Sex								
Female	217.6 ± 36.3	<0.001	39.0 ± 28.0	0.645	53 (7.3)	0.208	1.5 ± 0.8	0.037
Male	207.5 ± 33.0		40.3 ± 61.7		45 (9.4)		1.4 ± 0.6	
Side								
Right	220.5 ± 35.9	0.278	31.3 ± 5.0	0.500	2 (11.8)	0.643*	1.5 ± 0.9	0.871
Left	211.3 ± 34.7		39.9 ± 51.2		96 (8.1)		1.4 ± 0.7	
Body mass index, kg^2/m								
<18.5	207.3 ± 44.0	<0.001	41.2 ± 31.0	0.565	3 (17.7)	0.383	1.6 ± 0.7	0.520
18.5–25	206.3 ± 32.4		41.0 ± 70.9		38 (7.7)		1.4 ± 0.6	
25.1–30	214.4 ± 35.0		36.7 ± 21.1		34 (7.4)		1.4 ± 0.7	
>30	221.3 ± 39.1		36.4 ± 21.6		12 (9.9)		1.4 ± 0.6	
Renal arteries, no.								
1	209.0 ± 34.2	<0.001	39.9 ± 56.2	0.671	77 (8.7)	0.014	1.4 ± 0.7	0.671
2	216.3 ± 35.5		38.4 ± 30.3		15 (5.4)		1.4 ± 0.8	
≥3	235.6 ± 31.4		47.0 ± 44.0		6 (20.0)		1.4 ± 0.5	
Early branch								
Yes	218.0 ± 33.3	0.002	43.9 ± 95.5	0.159	21 (8.4)	0.6329	1.5 ± 0.8	0.564
No	209.8 ± 35.0		38.8 ± 30.0		77 (8.2)		1.4 ± 0.7	
Renal veins, no.								
1	211.4 ± 35.0	0.671	40.0 ± 52.2	0.650	95 (8.3)	0.619*	1.4 ± 0.7	0.801
≥2	213.7 ± 29.0		36.8 ± 17.2		3 (5.3)		1.5 ± 0.7	
Late confluence								
Yes	215.0 ± 37.1	0.101	37.0 ± 24.1	0.354	32 (13.9)	0.001	1.4 ± 0.6	0.100
No	210.6 ± 34.1		40.5 ± 55.6		66 (6.9)		1.5 ± 0.7	

* *p* values are from the Fisher exact test, due to the small cell value. All *p* values are calculated based on the cohort without unknown category.

operative times [14]. Fettouh demonstrated that vascular anomalies (multiple renal arteries and veins, retroaortic and circumaortic renal veins) prolonged the operative time but did not affect warm ischemia time, blood loss, or LOS [15]. Our study, however, is the first to demonstrate that early renal artery branching prolongs operative time, likely due to the additional care and caution required to avoid vascular injury. For instance, for cases with multiple arteries that originate a significant distance apart, more dissection time is required to ensure maximal arterial length, particularly when separate firing of the endovascular stapler is needed. Longer operative time was also observed during female LDN. Others have shown that female versus male laparoscopic nephrectomy for malignancy is associated with more blood transfusions and prolonged LOS [16]. However, Jacobs et al. did not find differences in operative time by sex [17]. Finally, our finding of longer operative time in female patients is surprising given our observation that women generally have less perinephric and mesenteric fat than men of the same BMI.

Table 4 – Multivariable regression for factors associated with operative time, estimated blood loss, complications, and length of stay

	Operative time			Estimated blood loss			Complications			Length of stay		
	PE	SE	*p*	PE	SE	*p*	OR	95% CI	*p*	PE	SE	*p*
Age	0.08	0.11	0.484	−0.01	0.14	0.923	0.996	0.98–1.02	0.711	−0.003	0.00	0.124
Body mass index, kg^2/m	1.03	0.32	0.001	−0.56	0.43	0.190	1.003	0.94–1.07	0.926	0.001	0.01	0.879
Sex (referent: male)												
Female	9.09	2.43	<0.001	−2.35	3.28	0.475	0.81	0.51–1.28	0.367	0.04	0.04	0.432
Side (referent: left)												
Right	12.05	8.71	0.167	−8.80	13.34	0.510	2.49	0.53–11.76	0.251	0.13	0.16	0.432
Renal arteries, no. (referent: 1)												
2	7.87	2.70	0.004	−10.30	10.00	0.304	0.67	0.38–1.21	0.185	0.06	0.13	0.658
≥3	22.45	7.13	0.002	−13.73	10.33	0.184	2.74	1.05–7.16	0.040	0.04	0.13	0.745
Renal veins, no. (referent: 1)												
≥2	1.61	5.78	0.781	−4.27	7.48	0.568	0.67	0.20–2.25	0.520	0.04	0.11	0.690
Early branch (referent: none)	5.67	2.82	0.045	7.81	3.85	0.043	0.94	0.54–1.63	0.812	0.05	0.05	0.344
Late confluence (referent: none)	2.71	2.79	0.333	−3.50	3.95	0.375	2.42	1.50–3.91	0.0003	−0.02	0.05	0.715

PE = parameter estimate; SE = standard error; OR = odds ratio; CI = confidence interval.

Second, three or more renal arteries and late renal vein confluence were associated with more complications. In terms of late renal vein confluence, Roman et al. noted that 81% of late renal vein confluences were associated with lumbar or gonadal vein diameters ≥5 mm, and this association may contribute to the greater risk for complications [18]. Interestingly, others have shown that multiple renal arteries are associated with a higher risk of ureteral stricture in the recipient [19,20]. While we previously examined our outcomes and did not find an association between multiple renal arteries and a higher risk for ureteral stricture, prior analysis did not adjust for potential confounders such as independent variables of interest [21]. Most prior studies of donor nephrectomies dichotomize into single versus multiple renal arteries. Hsu et al. reported that multiple renal arteries were associated with longer operative time but not with more complications [22]. This was corroborated by other single-institution series that demonstrated that vascular anomalies were not associated with more complications [23,24]. Additionally, we did not find that right versus left LDN was associated with more complications although we seldom perform right LDN and, therefore, our analysis is limited. Mandal et al. found that left-sided LDN was technically easier; they concluded that right-sided LDN may be performed safely with proper patient selection beyond their early LDN experience, during which there were more complications with right versus left LDN [25]. However, this difference in complications resolved after technical modification, and others have not observed differences in right-sided versus left-sided LDN complications [26]. There is one center to our knowledge that preferentially takes the right kidney because there are no lumbar veins and it has very good outcomes [27]. Finally, older age was not associated with more complications consistent with others' findings [17] and this may be secondary to selection bias for healthy surgical candidates.

Third, while early renal arterial branching was associated with greater EBL, other factors such as BMI, number of renal vessels, and late renal vein confluence did not affect EBL. Kok et al. reported that multiple arteries versus a single renal artery was associated with higher blood loss [28]. While our study is the first to demonstrate that early renal artery branching is associated with higher blood loss, our findings must be tempered by statistical versus clinical significance in that the mean EBL in our series was 40 ml.

Older age, higher BMI, and renal vascular variation did not affect LOS in our cohort. Similarly, Jacobs et al. reported that older age did not affect LOS [17]. Heimbach et al. demonstrated that higher BMI did not prolong length of stay [14]. In addition, Paragi et al. previously showed that the number of renal vessels did not affect LOS [29].

Our study must be interpreted in the context of the study design (ie, a retrospective, single-center study at a high-volume academic program). First, intraoperative LDN training of fellows and residents occurred routinely and we did not quantify the duration or operative steps that involved training, which may affect outcomes such as operative time. Second, we developed a LDN collaborative care pathway that may limit heterogeneity in LOS and limit our ability to identify factors associated with prolonged LOS. Third, while our analysis demonstrates statistically significant findings, the clinical significance must be weighed carefully. For instance, our analysis identified predictor variables for higher blood loss, however donors did not require blood transfusions. Similarly, the majority of our complications were Clavien grade 1 and 2a. However, donors are uniquely healthy patients who would not have experienced complications in the absence of LDN. Moreover, we did not prospectively record the warm ischemia time, and, therefore, we are unable to assess its affect on donor graft outcomes. However, the UCLA 1-yr actual versus expected donor graft survival is 95.8% versus 94.6% relative to the national average of 93.8% [30], and multiple factors in addition to warm ischemia time affect graft survival and function, such as ABO and human leukocyte antigen compatibility, prior sensitization and transplantation, donor and recipient age, recipient sex and ethnicity, and so on. Finally, fellowship-trained urologists performed LDN (with the majority by PS), and our findings may not be generalizable to other practice settings.

Albeit complex vascular anatomy is not a contraindication to LDN, we feel that high-volume centers and surgeons with experience in complex vascular cases should undertake such cases carefully given the findings in this study. Informing patients of the potential limitations and complications is paramount and exhaustion of all other donor options should be emphasized and explored prior to undertaking a more complex vascular anatomy case.

5. Conclusions

The number of renal arteries, early renal arterial branching, and late renal vein confluence affect LDN operative time, EBL, and complications. These factors should be considered in training centers, particularly during the early LDN learning curve. While complicated donor anatomy is not a contraindication of kidney donation, we routinely inform potential donors of these results at our institution.

Author contributions: Jim C. Hu had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Hu, Schulam, Gritsch, Veale, Blumberg, Ernest.
Acquisition of data: Liu, Carter, Treat.
Analysis and interpretation of data: Hu, Schulam, Gritsch, Veale, Blumberg, Ernest, Treat.
Drafting of the manuscript: Hu, Liu, Huang, Carter, Treat.
Critical revision of the manuscript for important intellectual content: Hu, Treat.
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References

[1] Davis CL. Living-donor kidney transplantation: a review of the current practices for the live donor. J Am Soc Nephrol 2005;16:2098–110.

[2] Rettkowski O, Hamza A, Markau S, Osten B, Fornara P. Ten years of laparoscopic living donor nephrectomy: retrospect and prospect from the nephrologist's point of view. Transplant Proc 2007;39:30–3.

[3] Alcaraz A, Rosales A, Guirado L, Díaz JM, Musquera M, Villavicencio H. Early experience of a living donor kidney transplant program. Eur Urol 2006;50:542–8.

[4] Ekser B, Furian L, Rigotti P. Optimizing allocation of kidneys from older donors: between resources and results. Am J Transplant 2011;11:182, author reply 183.

[5] Montgomery RA, Katznelson S, Bry WI, et al. Successful three-way kidney paired donation with cross-country live donor allograft transport. Am J Transplant 2008;8:2163–8.

[6] Andersen MH, Mathisen L, Oyen O, et al. Postoperative pain and convalescence in living kidney donors-laparoscopic versus open donor nephrectomy: a randomized study. Am J Transplant 2006;6:1438–43.

[7] Greco F, Hoda MR, Alcaraz A, Bachmann A, Hakenberg OW, Fornara P. Laparoscopic living-donor nephrectomy: analysis of the existing literature. Eur Urol 2010;58:498–509.

[8] Segev DL. Innovative strategies in living donor kidney transplantation. Nat Rev Nephrol 2012;8:332–8.

[9] Breda A, Veale J, Liao J, Schulam PG. Complications of Laparoscopic living donor nephrectomy and their management: the UCLA experience. Urology 2007;69:49–52.

[10] Harper JD, Leppert JT, Breda A, Schulam PG. Standardized Linear port configuration to improve operative ergonomics in laparoscopic renal and adrenal surgery: experience with 1264 cases. J Endourol 2011;25:1769–73.

[11] Kocak B, Koffron AJ, Baker TB, et al. Proposed classification of complications after live donor nephrectomy. Urology 2006;67:927–31.

[12] Ratner LE, Ciseck LJ, Moore RG, Cigarroa FG, Kaufman HS, Kavoussi LR. Laparoscopic live donor nephrectomy. Transplantation 1995;60:1047–9.

[13] Genc V, Karaca AS, Orozakunov E, et al. Multiple renal arteries challenge in laparoscopic donor nephrectomy: how far can we go? J Korean Surg Soc 2011;80:272.

[14] Heimbach JK, Taler SJ, Prieto M, et al. Obesity in living kidney donors: clinical characteristics and outcomes in the era of laparoscopic donor nephrectomy. Am J Transplant 2005;5:1057–64.

[15] Fettouh HA. Laparoscopic donor nephrectomy in the presence of vascular anomalies: evaluation of outcome. J Endourol 2008;22:77–82.

[16] Sammon J, Trinh Q-D, Sun M, et al. The effect of gender on nephrectomy perioperative outcomes: a national survey. Can J Urol 2012;19:6337–44.

[17] Jacobs SC, Ramey JR, Sklar GN, Bartlett ST. Laparoscopic kidney donation from patients older than 60 years. J Am Coll Surg 2004;198:892–7.

[18] Raman SS, Pojchamarmwiputh S, Muangsomboon K, Schulam PG, Gritsch HA, Lu DS. Surgically relevant normal and variant renal parenchymal and vascular anatomy in preoperative 16-MDCT evaluation of potential laparoscopic renal donors. Am J Roentgenol 2011;188:1941–6.

[19] Carter JT, Freise CE, McTaggart RA. Laparoscopic procurement of kidneys with multiple renal arteries is associated with increased ureteral complications in the recipient. Am J Transplant 2005;5:1312–8.

[20] Fuller TF, Deger S, Büchler A, et al. Ureteral complications in the renal transplant recipient after laparoscopic living donor nephrectomy. Eur Urol 2006;50:535–41.

[21] Breda A, Bui MH, Liao JC, Gritsch HA, Schulam PG. Incidence of ureteral strictures after laparoscopic donor nephrectomy. J Urol 2006;176:1065–8.

[22] Hsu THS, Su LI-M, Ratner LE, Trock BJ, Kavoussi LR. Impact of renal artery multiplicity on outcomes of renal donors and recipients in laparoscopic donor nephrectomy. Urology 2003;61:323–7.

[23] Saidi R, Kawai T, Kennealey P, et al. Living donor kidney transplantation with multiple arteries: recent increase in modern era of laparoscopic donor nephrectomy. Arch Surg 2009;144:472–5.

[24] Disick GIS, Shapiro ME, Miles RA, Munver R. Critical analysis of laparoscopic donor nephrectomy in the setting of complex renal vasculature: initial experience and intermediate outcomes. J Endourol 2009;23:451–5.

[25] Mandal AK, Cohen C, Montgomery RA, Kavoussi LR, Ratner LE. Should the indications for laparoscopic live donor nephrectomy of the right kidney be the same as for the open procedure? Anomalous left renal vasculature is not a contraindication to laparoscopic left donor nephrectomy Transplantation 2001;71:660–4.

[26] Tsoulfas G, Agorastou P, Ko D, et al. Laparoscopic living donor nephrectomy: is there a difference between using a left or a right kidney? Transplant Proc 2012;44:2706–8.

[27] Dols LFC, Kok NFM, Alwayn IPJ, Tran TCK, Weimar W, Ijzermans JNM. Laparoscopic donor nephrectomy: a plea for the right-sided approach. Transplantation 2009;87:745–50.

[28] Kok NFM, Dols LFC, Hunink MGM, et al. Complex vascular anatomy in live kidney donation: imaging and consequences for clinical outcome. Transplantation 2008;85:1760–5.

[29] Paragi PR, Klaassen Z, Fletcher HS, et al. Vascular constraints in laparoscopic renal allograft: comparative analysis of multiple and single renal arteries in 976 laparoscopic donor nephrectomies. World J Surg 2011;35:2159–66.

[30] Scientific Registry of Transplant Recipients. US hospitals with kidney transplant centers. Scientific Registry of Transplant Recipients Web site. http://www.srtr.org/csr/current/Centers/TransplantCenters.aspx?organcode=KI. Accessed September 17, 2013.

Evolution of Laparoscopic Donor Nephrectomy Technique and Outcomes: A Single-center Experience With More Than 1300 Cases

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OBJECTIVE To describe and illustrate the evolution of surgical technique, emphasizing technical modifications of laparoscopic donor nephrectomy (LDN) and the impact on complication outcome.

METHODS This is a retrospective observational study of prospectively collected data on all consecutive purely LDN surgeries performed at a tertiary academic medical center (n = 1325), performed between March 2000 and October 2013.

RESULTS Over time, LDN was performed on older patients, changing from a mean of 35.7 years in 2000 to 41.2 years in 2013 (P <.001). Additionally, mean blood loss decreased from 75 mL in 2000 to 21.6 mL in 2013 (P <.001). However, body mass index, operative time, and length of stay remained similar. Overall, there were 105 (7.9%) complications: Clavien grade 1 (n = 81, 6.1%) and grade 2 or higher (n = 23, 1.8%). Procedure duration, blood loss, surgeon, year of procedure, laterality, body mass index, age, and gender did not significantly predict complications. There was no significant difference for Clavien complication rates between the early learning period (first 150 cases) and the rest of the series.

CONCLUSION With continual refinement with LDN techniques based on intraoperative observations and technological advances, complication rates remain consistently low, despite increasing donor age. UROLOGY 85: 107–112, 2015.

Laparoscopic techniques improve morbidity and shorten convalescence for donor nephrectomy.[1] However, in contrast to kidney surgeries eliminating cancer, infection, or obstruction, laparoscopic donor nephrectomy (LDN) risks donor health without improving it. Thus, the challenge for LDN is to relentlessly pursue the refinement of surgical technique to reduce risk to the donor. Continuous quality improvement should accompany advances in surgical technology and technique. Although population-based studies demonstrate better donor nephrectomy outcomes over time, these may not include subtle details that incrementally improve the donor experience.[2] Herein, we aim to describe the evolution of surgical technique, emphasizing technical modifications and the impact on complication outcome with a single institution's LDN experience.

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METHODS

Patient Selection

This is a retrospective observational study of prospectively collected data on all consecutive purely LDN surgeries performed at a tertiary academic medical center (University of California, Los Angeles, CA) since March 2000 through October 2013. LDN patient selection and workup has been described previously.[3] In 98% of cases, the patient's kidneys were equivalent by imaging; therefore, based on surgeon preference for longer vein length, the left kidney was routinely removed. For brevity, this surgical description will focus on the left-sided procedure. Of note, the right kidney was taken typically in instances of minor nephrolithiasis or small renal defects.

Surgical Technique

The supplementary video depicts a typical left LDN to accompany this description (Video).

Patient Positioning. After anesthesia induction, an oral gastric tube is placed to decompress the stomach. Additionally, the Pfannenstiel incision is premarked in the supine position (lower transverse approximately 8 cm in length, 3 cm above the

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symphysis pubis) to prevent an asymmetric skin incision resulting from gravity's effect on the pannus in flank position. The patient is positioned into a modified flank or right lateral decubitus position (Supplementary Fig. 1). Early in our experience, the left arm was extended and abducted, supported by an airplane armrest over the right arm. However, since 2012, we place the arm in a neutral position along the left lateral torso in an adducted anatomic position because we observed that this position was associated with less limitations of instrument range during robotic-assisted transperitoneal partial nephrectomy. Before this modification, the laparoscope range of motion was limited by the ipsilateral arm position on the airplane. Moreover, this positioning eliminates the need for an airplane, and there is adequate space for open conversion through a subcostal incision. Once positioned, a 10-cm cloth tape is used to secure the patient at the chest, hips, and ipsilateral arm, and the first 12.5-gm intravenous mannitol dose is administered.

Trocar Placement. Pneumoperitoneum is obtained using a Veress needle placed 0.5 cm cephalad to the umbilicus. Before 2006, the Veress needle was placed in the left lower quadrant; however, we adjusted placement after an injury to the left common iliac artery. After achieving 15 mm Hg of insufflation, three 5-mm trocars are placed along the left rectus margin in a linear configuration.[4] Before 2005, before the advent of high-definition cameras, we used 12-mm trocars, but the switch obviates trocar fascial closure with endoclose devices that often snare the rectus muscle and contribute to postoperative discomfort. Next, an optical obturator 5-mm trocar with a 0° scope is advanced under direct vision at the junction of the rectus border and costal margin (approximately 1 cm inferior to rib). We switch to the 30° laparoscope and place the next two 5-mm trocars under direct vision, spaced approximately 7 cm apart, respectively.

Reflection of Descending Colon. The assistant operates the camera through the most cephalad trocar. We routinely used a fourth 5-mm trocar under the costal margin at the anterior axillary line and a second assistant to facilitate lateral traction on the kidney during the medial upper pole and hilar dissections; however, this was eliminated in 2012 in favor of a 3-trocar technique. The white line of Toldt is incised approximately 1 cm lateral to the descending colon into the pelvis. Over the kidney, care is taken only to incise the peritoneal layer to preserve an anatomic approach, and not enter the Gerota fascia. Moreover, entry into the Gerota fascia over the kidney obscures the hilar dissection, as the Gerota fascia (and perinephric fat) falls medially over the hilum. Caudad to the kidney, a combination of sharp or blunt dissection is used to sweep the peritoneum medially. Spinning a laparoscopic Kittner medially while maintaining lateral counter traction with a blunt tip grasper is very effective to avoid an inadvertent peritoneal window. With more medial reflection of the peritoneum, the gonadal vein is identified coursing just under the mildly transparent Gerota fascia.

This dissection plane of the peritoneal reflection medially and inferiorly away from the Gerota fascia is carried lateral to the tail of the pancreas and approximately 1 cm lateral to the spleen. The incision of the peritoneum needs to be carried up superiorly well above the spleen to ensure adequate exposure for the medial upper pole dissection (Supplementary Fig. 2A).

Gonadal Vein, Ureteral, and Posterior Dissection. We dissect around the gondal vein, just below the lower pole where it crosses over the ureter (Supplementary Fig. 2B). Next, we divide the somewhat opaque Gerota fascia overlying the gonadal vein in a cephalad direction, facilitating the identification of the renal vein. Extending this dissection of the Gerota fascia more cephalad across the renal vein often reveals the confluence of the adrenal and renal vein more medial to the takeoff of the gonadal vein. The vessel sealer and divider (VSAD; LigaSure; Covidien, Norwalk, CT) is then used to ligate and divide the gonadal vein. We used the harmonic scalpel exclusively until 2006; however, we switched to the VSAD due to the consistent ligation of the gonadal, adrenal, and lumbar veins thus avoiding clips near the hilum that may increase the subsequent risk of stapler misfire. In our initial experience, we did not routinely ligate and divide the adrenal vein due to the inability of the harmonic scalpel to easily seal the adrenal vein. Therefore, we stapled the vein distal to the adrenal vein takeoff early in our experience. Additionally, the VSAD facilitates blunt dissection without the concern of thermal injury, whereas the harmonic scalpel has a sharper, hotter tip.

After gonadal vein division, we bluntly dissect onto the psoas muscle fascia, establishing the medial border of the ureteral dissection. Initially, we ligated and divided the gonadal vein just proximal to where the ureter crosses the common iliac artery with the intent of maximal preservation of ureteral vasculature; however, since 2007, we routinely ligate the gonadal vein just below the level of the lower pole because others have shown that this provides less postoperative ipsilateral scrotal discomfort in male donors with higher ligation.[5] The plane between the ureter and gonadal vein is established with sharp and blunt downward sweeping motions. The ureteral dissection ceases at the common iliac artery, but the ureter is not divided until after hilar vessels are divided to provide a point of fixation during hilar division and to prevent the ureter from flopping into areas of subsequent dissection, such as the hilum, and so forth.

Next, dissection is carried medial to the proximal gonadal vein stump toward the renal vein; however, this dissection ceases before lumbar veins are encountered typically inserting into the renal vein at the same level as the gonadal vein. The 30° scope is angled to visualize behind the kidney toward the upper pole, whereas blunt dissection is used to elevate the kidney off the psoas and quadratus muscle fascia. This release ensures renal vessel length through by enabling maximal stretch of the hilar vessels.

Upper Pole and Adrenal Gland Dissection. After reflecting the tail of the pancreas away from the medial upper pole, we enter the Gerota fascia, dissecting into the perinephric fat. First, the lateral edge of the adrenal gland is identified, and the dissection plane is carried as medial and as close to the adrenal gland as possible, to prevent potential injury to hilar branches to the upper pole (Supplementary Fig. 2C). This is carried down to the posterior body wall musculature, and extended superolaterally resulting in complete release of the upper pole of the kidney from the spleen. With the harmonic scalpel, we frequently encountered small vessel bleeding during dissection into the perinephric fat. However, this ceased with conversion to the VSAD, which also allows more 1-handed dissection due to secure hemostasis and led to the elimination of the fourth 5-mm port. Next, the adrenal vein is divided, and the upper edge of the renal vein proximal to the adrenal vein stump is released with blunt dissection to prepare the exit site of the endovascular stapler.

Hilar Dissection and Specimen Extraction. We coordinate with the recipient surgeon progress before extraction site incision to minimize cold ischemia time. The second 12.5-g mannitol dose is administered. A horizontal incision is made down to the anterior rectus sheath. The fascia is cleared superiorly toward the umbilicus to allow for a vertical midline incision through the fascia, splitting the bellies of the rectus muscle. The laparoscopic view of the convergence of the medial umbilical ligaments facilitates identification of midline. A cephalad fascial incision is made to accommodate the 15-mm trocar, and the 1-cm bridge of the fascia is left intact to hold the trocar circumferentially, and the vertical anterior rectus sheath fascial incision is continued caudad to total approximately 12 cm. Before 2005, we did not use this 1-cm fascial bridge, and there was frequent tearing of the peritoneum stemming from the fulcrum of the trocar and stapler and leakage of CO_2 insufflation at the inferior aspect of the 15-mm port during a critical time.

After preparing the extraction site, lumbar veins are divided to maximize vessel length. The laparoscopic suction tip is passed through the 15-mm trocar and slid next to the aorta behind the renal vein, entering and exiting proximal to the gonadal and adrenal vein stumps, respectively. Formerly, we meticulously dissected out the renal artery to its origin from the aorta; however, this was associated with an increased risk of lymphocele and bleeding from the vasa vasorum. In 2006, we switched to thinning out a pedicle behind the renal vein medially and the posterior body wall laterally. The lateral attachments of the kidney are divided, freeing the kidney completely with the exception of the hilum and ureter.

The surgeon elevates the kidney with 2 blunt tip instruments straddling the hilum (Supplementary Fig. 3A-C) and gives the assistant the cephalad instrument while holding the caudad one and firing the laparoscopic articulating gastrointestinal anastomosis stapler (Endo GIA; Covidien, Norwalk, CT) with vascular 60-mm loads to divide the renal artery followed by the vein along the path established by the suction tip. A liver retractor was placed through a fourth 5-mm trocar in the anterior axillary line, to elevate the upper pole; however, this was parsimoniously eliminated in 2012 in favor of the "chopsticks" elevation technique. Additionally, although some institutions prefer the thoracoabdominal laparoscopic stapler (Covidien) due to the theoretical advantage of gaining a millimeter from the absence of staple lines on the specimen side, using the laparoscopic scissors to cut beyond the staple line is an extra step that may prolong ischemia time compared with the firing and cutting of an endo gastrointestinal anastomosis stapler, and there is an additional iatrogenic risk of using scissors in a training center and/or cutting a serrated edge of the vessel that must be subsequently trimmed. Next, the ureter is tented upward, and a large Weck clip (Teleflex, Research Triangle Park, NC) is applied before sharp division proximal to the clip, over the common iliac artery. After the kidney is placed in the laparoscopic bag, cautery is used to divide the fascial bridge, preperitoneal fat, and peritoneum. Once extracted, the kidney is removed from the bag and immediately cooled in iced saline. The staple lines are trimmed, and the renal artery is gently dilated with a hemostat and flushed with 400 mL of heparinized (5000 units per liter) Lactated Ringer solution (University of Wisconsin solution for export exchanges).

Closure. The anterior rectus fascia is closed with a running monofilament absorbable suture. Insufflation is resumed and the surgical field is inspected for hemostasis. The laparoscopic sucker is used to extract as much CO_2 as possible before trocar removal to lessen the likelihood of postoperative shoulder or chest discomfort due to CO_2 diaphragmatic irritation. The incisions are infiltrated with 0.5% bupivacaine, and the skin is closed with absorbable monofilament suture. Intravenous ketorolac is given 0.5 mg/kg and continued until discharge.[6]

Table 1. Laparoscopic donor nephrectomy characteristics (n = 1325)

Characteristic	
Age, mean (range), y	41.4 (18-70)
Body mass index, mean (range), kg/m^2	25.8 (14-39)
Length of stay, mean (range), d	1.37 (1–10)
Estimated blood loss, mean (range), mL	38.3 (0-1500)
Operative time, mean (range), min	209.8 (72-445)
Female, n (%)	802 (60.5)
Left side, n (%)	1306 (98.6)
Arterial anatomy, n (%)	
Number of arteries	
1	976 (73.7)
2	305 (23.0)
3	30 (2.3)
4	3 (0.2)
Early bifurcation	265 (20)
Venous anatomy, n (%)	
Number of veins	
1	1248 (94.1)
2	62 (4.7)
3	5 (0.4)
Circumaortic	78 (5.9)
Retroaortic	39 (2.9)
Late confluence	254 (19.1)
Ureteral duplication, n (%)	17 (1.3)
Open conversions, n (%)	3 (0.2)

Data Collection and Analysis

Clinical data was prospectively collected with institutional review board approval. The modified Clavien classification was used to categorize complications and independently assessed by 2 separate reviewers to ensure data quality.[7] Descriptive statistics along with general linear regression were used to assess temporal trends and univariate logistic regression modeling for determining predictors of complications. Significance was determined at the $P \leq .05$ level. Statistical analysis was performed using R statistical software version 3.0.2.

RESULTS

Table 1 summarizes demographic and procedure characteristics of the 1325 LDNs performed from March 2000 and October 2013. Over time, LDN was performed on older patients changing from a mean of 35.7 (standard deviation [SD] ± 12.6) years in 2000 to 41.2 years (SD ± 11.0 years) in 2013 (Student t test, $P = .04$; $R^2 = 0.01$; $P < .001$). Additionally, blood loss decreased from a mean of 75 mL (SD ± 100 mL) in 2000 to 21.6 mL (SD ± 28.7 mL) in 2013 (Student t test, $P = .06$; $R^2 = 0.001$; $P < .001$). However, body mass index (BMI), gender, operative time, and length of stay (LOS) remained consistent without any trends. Mean warm ischemia time was 260 seconds (SD ± 61.2 seconds). Overall 1-year graft survival was 97.7%.

Table 2. Complications by modified donor Clavien classification

Complication by Clavien Class	*n*	%
Overall	105	7.9
Class 1	81	6.1
Wound infection	18	
Seroma	16	
Hematoma	12	
Pain (scrotal)	9	
Acute urinary retention	5	
Pain (NOS)	4	
Constipation	3	
Dermatitis	2	
Nausea/vomiting	2	
Urinary tract infection	2	
Acute renal injury	1	
Fever	1	
Ileus	1	
Numbness (face)	1	
Pleural effusion	1	
Pneumothorax	1	
Rash	1	
Vertigo	1	
Class 2a	13	0.98
Nausea/vomiting	3	
Acute renal injury	1	
Aspiration pneumonia	1	
Bleeding (required transfusion)	1	
Deep vein thrombosis	1	
Fever	1	
Lower extremity swelling (not DVT)	1	
Pain (abdominal)	1	
Pain (nonspecific)	1	
Shortness of breath	1	
Urticaria	1	
Class 2b	9	0.68
Incisional hernia	2	
Appendicitis	1	
Bleeding (required reoperation)	1	
Chylous ascites	1	
Hematoma	1	
Hematoma with subcutaneous drain	1	
Internal hernia	1	
Reintubation	1	
Class 2c	2	0.15
Veress needle injury to iliac artery	1	
Stapler misfire	1	

DVT, deep vein thrombosis; NOS, non-specific.

Overall, there were 105 (7.9%) LDN complications (Table 2). The majority were grade 1 (n = 81, 6.1%) and only 23 (1.8%) were grade 2 complications or higher. Procedure duration, blood loss, surgeon, year of procedure, laterality, BMI, age, and gender did not significantly predict complications. There was no significant difference for Clavien complication rates between the early learning period (first 150 cases) and the rest of the series (grade 1 odds ratio, 0.49; 95% confidence interval, 0.20-1.25 and grade 2 odds ratio, 1.12; 95% confidence interval, 0.33-3.81).

Technical modifications were often made in response to a complication or a technological development and are summarized in Table 3. Six LDNs required reoperation. One experienced an 11-cm subcutaneous hematoma that required drainage under anesthesia 2 weeks after LDN. Two patients required outpatient incisional hernia repair. Another LDN developed acute appendicitis 4 days postoperatively and needed appendectomy. One LDN required blood transfusion for postoperative bleeding on postoperative day 1 and on exploration; no identifiable source of bleeding was identified after clot evacuation. Finally, an LDN required re-exploration and repair of an internal hernia through a mesenteric defect. Conversion to open nephrectomy occurred in 2000, 2002, and 2005 because of stapler misfire, a Veress injury to the left common iliac artery, and failure to progress due to increased BMI.

COMMENT

This study describes the evolution of the surgical technique and shows that complication rates remained low and consistent, even within the early learning curve in our LDN experience at an academic teaching hospital. Many specific technical modifications were made, often in response to rare complications, whereas some modifications paralleled advances in technology (Table 3). Overall, the complication rate did not change significantly despite these changes. This finding is not surprising when considering how rare complication events occur with LDN, in general. The small benefit of technical changes may have been offset by the increasing risk profiles in donor selection over time.

Changes in donor age over the 14-year study period parallel national trends. Schold et al[2] analyzed donor nephrectomy in the National Inpatient Sample (NIS) representing 89% of all US donor nephrectomies during 1998-2010 and demonstrated similar age trends, with 40.1 years as the mean compared with 41.4 years in our most recent study year. Consistent with other US studies, mean BMI and proportion of female donors remained similar over time.[8]

Our LDN operative time did not change over time, consistent with other academic centers.[9] This likely stems from training of fellows and residents and the inherent nature of coordinated intrahospital exchanges to decrease cold ischemia time. However, Chin et al[10] demonstrated that operative time declined after the first 150 cases in a >500 LDN series. Unlike other series, the LOS in our study is relatively short (mean, 1.37 days) and remained unchanged. The mean LOS in other large LDN series ranges from 2.4 to 2.9 days; however, our technique is comprised pure laparoscopic procedure, whereas other reported series include open procedures or hand-assisted laparoscopic approaches.[10-12]

Although population-based studies based on administrative codes may offer a panoramic view, they may lack the reporting of minor complications that do not require a diagnosis code for billing purposes. For instance, Schold et al[2] reported an overall donor nephrectomy complication rate of 7.9% in the NIS, similar to ours. However, another NIS study of 6000 cases demonstrated an 18% complication rate during 1999-2005.[13] Yet, another NIS

Table 3. Surgical technical modifications over 1300 laparoscopic donor nephrectomy

Year	Observation/Complication	Modification
2002	Iliac artery injury	Veress needle placement at umbilicus, not in the left lower quadrant
2005	Stapler misfire	Single dedicated scrub technician for entire surgery to avoid unfamiliarity in loading and preparing endovascular
2005	Advent of high-definition camera	Port size change from 12 to 5 mm
2005	Leakage of CO_2/loss of exposure during stapling	Preserve 1-cm fascial band caudad to the 15-mm trocar for endovascular stapler
2005	Bowel injury secondary to heat from harmonic scalpel during laparoscopic partial nephrectomy	Cold scissor incision of white line of Toldt to reflect the descending colon medially
2006	Internal hernia	Closure of mesenteric defects with clips
2006	Avascular plane to the retroperitoneum	Laparoscopic Kittner to bluntly reflect peritoneum away from retroperitoneum based on anatomic observation that this plane is an avascular plane
2006	Chylous ascites	Shift from skeletonizing renal artery to aorta to thinning out arterial vascular pedicle before stapling
2008	Incisional hernia	Laparoscopic inspection of extraction site closure to ensure that bowel was not snared before trocar removal
2009	Secure hemostasis without clips	Switch from harmonic scalpel to VSAD to avoid clips near the hilum that may risk subsequent stapler misfire
2009	Switch to VSAD	Routine ligation of adrenal vein with VSAD to increase graft renal vein length
2010	Subcutaneous hematoma requiring surgical drainage	Placement of a closed suction subcutaneous drain at extraction site; discontinued in 2011 with occurrence of seromas and hematomas despite the drain
2012	Adoption from transperitoneal robotic partial nephrectomy	Ipsilateral arm positioning at patient's side rather than placement in airplane. More efficient positioning and improved laparoscope range of motion, particularly during ureteral dissection
2012	Switch to VSAD	Elimination of 4th port enabled by better hemostasis with VSAD, allowing 1-handed dissection. Switch from liver retractor to chopstick technique for kidney elevation during stapling

VSAD, vessel sealer and divider.

study showed a 0.6% complication rate through 2006 when using stringent outcomes definitions without appropriate weighting for NIS data.[14] Moreover, population-based studies are unable to distinguish surgical approaches such as open, hand-assisted laparoscopic, or pure LDN. Similarly, there is variation in single-center approaches, methodology, and reporting with overall complications ranging from 7% to 15%.[12,15,16]

Our findings must be interpreted in the context of our study design. Although there is significant variation in published donor nephrectomy outcomes due to differences in study design and definition of outcomes, LDN complications should occur infrequently, which limits our statistical power to assess uncommon events. However, our primary focus is to highlight technical changes over time and provide rationale for quality improvement that may be thought provoking for others performing similar procedures and those with considerable overlap with LDN, such as laparoscopic nephrectomy, nephroureterectomy, or partial nephrectomy. For instance, Birkmeyer et al[17] studied peer video review of laparoscopic bariatric surgery and found that greater technical skill was associated with fewer postoperative complications and fewer reoperations, readmission, and emergency department visits. Therefore, our main goal is to share technical changes that have improved our LDN experience. Moreover, 1 surgeon mentored the others and all performed LDN using the same steps, reinforcing the reproducibility of a consistent anatomic approach. Finally, although our data were collected prospectively, research personnel changed over the study and the reporting of minor complications may be subject to observer bias.

CONCLUSION

With continual refinement with LDN techniques based on intraoperative observations and technological advances, complication rates remain consistently low, despite increasing donor age.

References

1. Perry KT, Freedland SJ, Hu JC, et al. Quality of life, pain and return to normal activities following laparoscopic donor nephrectomy versus open mini-incision donor nephrectomy. *JURO*. 2003;169: 2018-2021.

2. Schold JD, Goldfarb DA, Buccini LD, et al. Comorbidity burden and perioperative complications for living kidney donors in the United States. *Clin J Am Soc Nephrol*. 2013;8:1773-1782.
3. Hu JC, Liu C-H, Treat EG, et al. Determinants of laparoscopic donor nephrectomy outcomes. *Eur Urol*. 2014;65:659-664.
4. Harper JD, Leppert JT, Breda A, et al. Standardized linear port configuration to improve operative ergonomics in laparoscopic renal and adrenal surgery: experience with 1264 cases. *J Endourol*. 2011; 25:1769-1773.
5. Gjertson CK, Sundaram CP. Testicular pain following laparoscopic renal surgery. *J Urol*. 2008;180:2037-2041.
6. Breda A, Bui MH, Liao JC, et al. Association of bowel rest and ketorolac analgesia with short hospital stay after laparoscopic donor nephrectomy. *Urology*. 2007;69:828-831.
7. Kocak B, Koffron AJ, Baker TB, et al. Proposed classification of complications after live donor nephrectomy. *Urology*. 2006;67:927-931.
8. Segev DL, Muzaale AD, Caffo BS, et al. Perioperative mortality and long-term survival following live kidney donation. *JAMA*. 2010; 303:959-966.
9. Jacobs SC, Cho E, Foster C, et al. Laparoscopic donor nephrectomy: the University of Maryland 6-year experience. *JURO*. 2004;171: 47-51.
10. Chin EH, Hazzan D, Edye M, et al. The first decade of a laparoscopic donor nephrectomy program: effect of surgeon and institution experience with 512 cases from 1996 to 2006. *J Am Coll Surg*. 2009;209:106-113.
11. Nicholson ML, Kaushik M, Lewis GRR, et al. Randomized clinical trial of laparoscopic versus open donor nephrectomy. *Br J Surg*. 2009;97:21-28.
12. Ramasamy R, Afaneh C, Katz M, et al. Comparison of complications of laparoscopic versus laparoendoscopic single site donor nephrectomy using the modified Clavien grading system. *JURO*. 2011; 186:1386-1390.
13. Friedman AL, Cheung K, Roman SA, et al. Early clinical and economic outcomes of patients undergoing living donor nephrectomy in the United States. *Arch Surg*. 2010;145:356-362; discussion 362.
14. Colombo B, Singla A, Li Y, et al. Current trends and short-term outcomes of live donor nephrectomy: a population-based analysis of the nationwide inpatient sample. *World J Surg*. 2010;34: 2985-2990.
15. Stamatakis L, Mercado MA, Choi JM, et al. Comparison of laparoendoscopic single site (LESS) and conventional laparoscopic donor nephrectomy at a single institution. *BJU Int*. 2013;112: 198-206.
16. Dols LF, Kok NF, d'Ancona FC, et al. Randomized controlled trial comparing hand-assisted retroperitoneoscopic versus standard laparoscopic donor nephrectomy. *Transplantation*. 2014;97:161-167.
17. Birkmeyer JD, Finks JF, O'Reilly A, et al. Surgical skill and complication rates after bariatric surgery. *N Engl J Med*. 2013;369: 1434-1442.

Video

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Oncology

Same day discharge robotic-assisted nephroureterectomy

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ABSTRACT

Minimally invasive radical nephroureterectomy (RNU) decreases length of hospital stay compared to open RNU. We describe and demonstrate with video the first report of an outpatient robotic RNU.

1. Introduction

Radical nephroureterectomy (RNU) is the gold standard treatment for high-grade upper tract urothelial carcinoma (UTUC). While endoscopic ablative therapies may be applied for high-grade UTUC in a solitary kidney, RNU is strongly preferred by professional guideline recommendations.

RNU may be performed via an open, laparoscopic, or robotic-assisted laparoscopic approach. Minimally invasive techniques decrease hospital stays from a median of 5 to 4 days, as well as the proportion of prolonged hospitalizations (≥7 days) from 30% to 20%.[1] RNU increased in popularity over both open and laparoscopic approaches following initial description in 2006.[2]

Moreover, same-day surgery (SDS) is safe and feasible for radical nephrectomy,[3] and we demonstrated that patients prefer SDS over an overnight stay for major urologic cancer operations such as radical prostatectomy.[4] To our knowledge, RNU has yet to be reported as an ambulatory procedure. As such, we build on our SDS robotic assisted radical prostatectomy and partial and radical nephrectomy experience to manage high-grade upper tract urothelial carcinoma with SDS robotic RNU.

2. Case presentation

A 65-year-old female was referred for gross hematuria. Her past medical history was significant for type I Von Willebrand's factor disorder and Hereditary nonpolyposis colorectal cancer syndrome. Her past surgical history was notable for total abdominal hysterectomy and bilateral salpingo-oophrectomy and multiple colonoscopies with removal of adenomatous colonic polyps. Her family history was significant for ovarian and breast (sister), colon (brother, mother, maternal grandmother), and prostate (brother) cancer. She denied a history of tobacco use.

A computed tomography (CT) of the abdomen and pelvis revealed a 3.0 × 2.7 × 2.3 cm lobulated, enhancing mass in the left renal pelvis (Fig. 1). Urine cytology was negative for high-grade urothelial carcinoma. Her preoperative creatinine was 0.89 mg/dL with an estimated glomerular filtration rate of 66 mL/min.

She underwent cystoscopy and left ureteroscopy which demonstrated a large mass within the renal pelvis. Biopsy confirmed the presence of high-grade papillary urothelial carcinoma. Patient was recommended for definitive treatment with RNU, and she elected to proceed with surgery. During preoperative clearance, her hematologist recommended administration of cryoprecipitate in the setting of intraoperative oozing/bleeding.

We performed robotic-assisted laparoscopic RNU with the Da Vinci Xi robotic platform as previously described.[5] The patient was placed in left lateral decubitus position with the left arm taped to the side of the body. Three 8 mm robotic ports were placed along the mid-clavicular line and one 12 mm assistant port was placed supra-umbilically (Fig. 2). In contrast to our early description,[5] rotation of the Xi robot on its boom precluded repositioning the patient or the robot between nephrectomy and ureterectomy. We demonstrate the procedure with video (Video).

Supplementary video related to this article can be found at https://doi.org/10.1016/j.eucr.2023.102490

The operative time was 115 min with a console time of 81 min and estimated blood loss was minimal. Ketorolac was administered prior to extubating. Postoperatively, the hematocrit was stable, and after 5 hours in the post-anesthesia care unit, she was given a second dose of intravenous ketorolac and discharged home. There was no need to administer cryoprecipitate. When given the choice to return for catheter removal vs.

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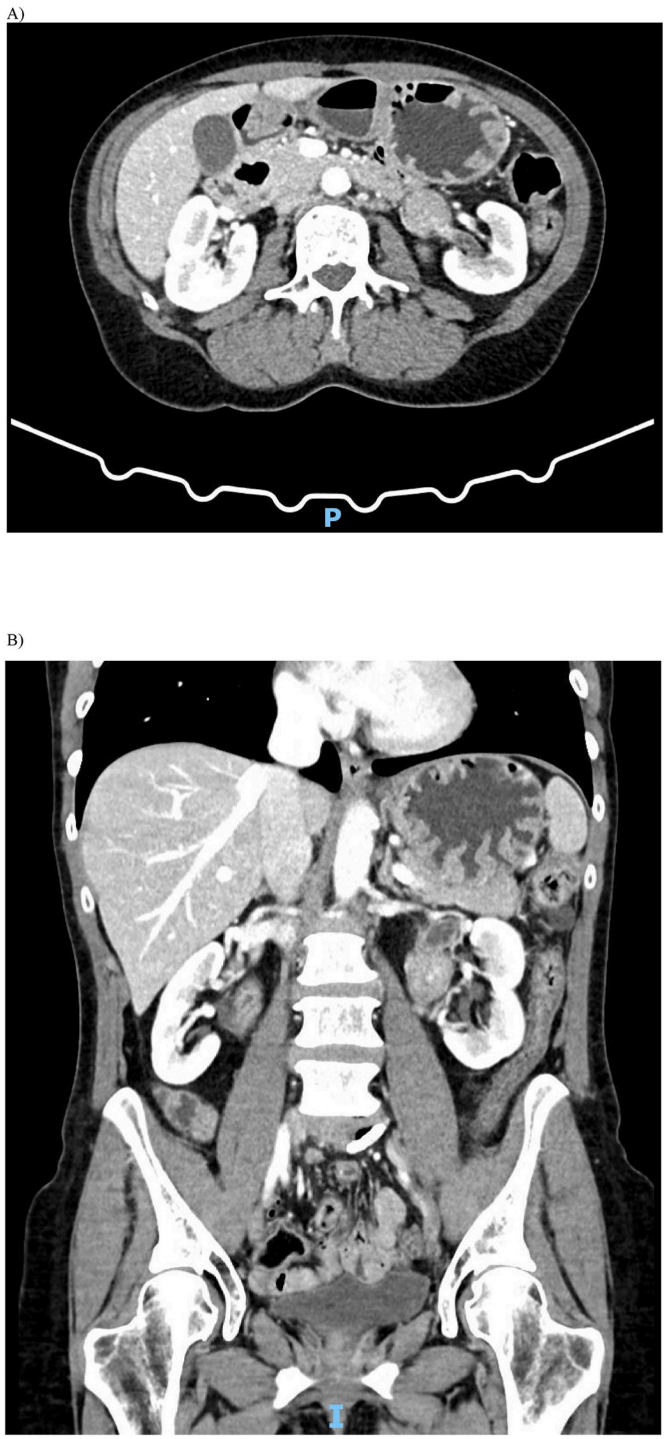

Fig. 1. Axial (A) and coronal (B) images of the computed tomography (CT) scan demonstrating a mass in the left renal pelvis.

self-removal, the patient elected to remove the catheter at home on postoperative day 5.

Pathological examination revealed 260 g nephroureterectomy specimen (Fig. 3) and a 3.5 cm renal pelvis tumor demonstrating invasive high-grade papillary urothelial carcinoma with tumor invading the lamina propria. All surgical margins, including the ureter, were negative for carcinoma.

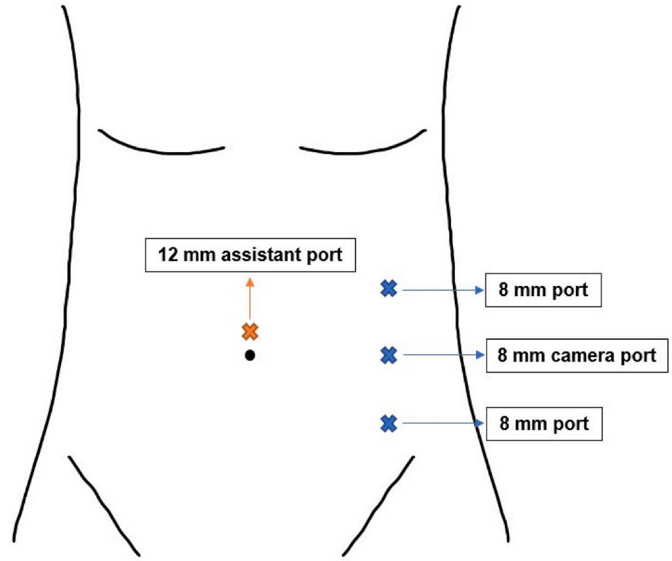

Fig. 2. Port placements for robotic-assisted nephroureterectomy.

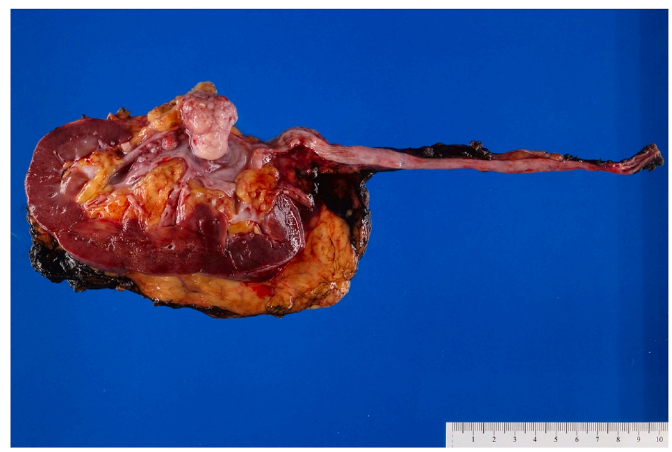

Fig. 3. Gross specimen of left kidney and ureter with renal pelvic mass.

3. Discussion

While RNU was traditionally performed via the open approach, the proportion of minimally invasive RNU increased from 36% to 54% during 2004–2013, largely due to adoption of the robotic approach.[2] Recent interest in performing SDS, particularly for prostatectomy and nephrectomy, increased due to the COVID-19 pandemic with the need to free up inpatient beds. When comparing SDS vs. inpatient radical prostatectomy, Cheng et al. demonstrated no differences in complications or patient satisfaction scores, and SDS vs. inpatient robotic assisted radical prostatectomy decreased healthcare costs by almost 20%.[4] Furthermore, when given the choice, 87% of men elected to undergo SDS rather than stay overnight.[4]

Same-day robotic RNU may provide similar cost-savings and may better align with patient preferences. We demonstrate that SDS RNU may be performed safely with comorbidities (von Willebrand factor disease). Factors associated with the feasibility of SDS for RNU include short operative time (115 min), the absence of a surgical drain, and avoidance of narcotic analgesics. Our protocol for outpatient robotic procedures includes early intraoperative administration of intravenous ketorolac and acetaminophen with redosing in the recovery room for optimal pain control. Patients are discharged on a clear liquid diet and instructed to gradually advance it on their own.

Our study is limited by retrospective review of a case report. Nevertheless, we demonstrate that robotic RNU is safe as an outpatient procedure. Future study is needed to better characterize outcomes of same-day robotic RNU.

4. Conclusion

We demonstrate that robotic RNU SDS is safe and feasible. Given similar outcomes to inpatient RNU with the absence of the healthcare cost of overnight hospital stay, robotic RNU SDS has higher value care, defined as healthcare outcomes divided by costs.

Disclosures

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Consent

Written consent was obtained from the patient prior to publication.

Declaration of competing interest

The authors have no conflicts of interest to report with regards to this case report.

References

1. Pearce SM, Pariser JJ, Patel SG, Steinberg GD, Shalhav AL, Smith ND. The effect of surgical approach on performance of lymphadenectomy and perioperative morbidity for radical nephroureterectomy. *Urol Oncol: Seminar Origin Investigat*. 2016;34(3). https://doi.org/10.1016/j.urolonc.2015.09.008, 121.e15-121.e21.
2. Tinay I, Gelpi-Hammerschmidt F, Leow JJ, et al. Trends in utilisation, perioperative outcomes, and costs of nephroureterectomies in the management of upper tract urothelial carcinoma: a 10-year population-based analysis. *BJU Int*. 2016;117(6): 954–960. https://doi.org/10.1111/bju.13375.
3. Azawi NH, Christensen T, Dahl C, Lund L. Laparoscopic nephrectomy as outpatient surgery. *J Urol*. 2016;195(6):1671–1676. https://doi.org/10.1016/j.juro.2015.12.088.
4. Cheng E, Laviana A, Basourakos S, et al. Mp77-13 outpatient versus inpatient robotic assisted radical prostatectomy: complications, time driven activities based costing and patient satisfaction. *J Urol*. 2023;209(suppl 4), e1107. https://doi.org/10.1097/JU.0000000000003351.13.
5. Hu JC, Silletti JP, Williams SB. Initial experience with robot-assisted minimally-invasive nephroureterectomy. *J Endourol*. 2008;22(4):699–704. https://doi.org/10.1089/end.2007.0333.