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Robotic versus Standard Laparoscopic Partial/Wedge Nephrectomy: A Comparison of Intraoperative and Perioperative Results from a Single Institution

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ABSTRACT

***Purpose*: Laparoscopic partial/wedge nephrectomy, similar to laparoscopic radical prostatectomy, is a technically challenging procedure that is performed by a limited number of expert laparoscopic surgeons. The incorporation of a robotic surgical interface has dramatically increased the use of minimally invasive pelvic surgery such that robotic laparoscopic radical prostatectomy is commonly performed even by laparoscopically naïve surgeons. This analysis compares the outcomes of our initial experience with robot-assisted laparoscopic partial nephrectomy (RLPN) performed by an experienced open surgeon to that of standard laparoscopic partial nephrectomy (LPN) performed by two experienced laparoscopic surgeons.**

***Patients and Methods*: We reviewed the medical records of 11 consecutive patients who underwent 12 standard LPNs (EMM, RVC) (one patient had two unilateral tumors) and 10 consecutive patients (representing the first 11 of such robotic procedures performed at our institution) who underwent 11 RLPNs (one patient had bilateral tumors managed in an asynchronous manner) (DKO).**

***Results*: The mean tumor size was 2.3 cm (range 1.7–6.2 cm) for LPN and 3.1 cm (range 2.5–4 cm) for RLPN. The mean total procedure time was 289.5 minutes (range 145–369 min) for LPN and 228.7 minutes (range 98–375 min) for RLPN ($P = 0.102$). The mean estimated blood loss was 198 mL (range 75–500 mL) for LPN *v* 115 mL (25–300 mL) for RLPN ($P = 0.169$). The mean warm ischemia time was 35.3 minutes (range 15–49 min) in the LPN group and 32.1 minutes (range 30–45 minutes) in the RLPN group ($P = 0.501$).**

***Conclusions*: Introducing a robotic interface for laparoscopic partial/wedge resection allowed a fellowship-trained urologic oncologist with limited reconstructive laparoscopic experience to achieve results comparable to those for laparoscopic partial/wedge resection performed by experienced laparoscopic surgeons. In this regard, the learning curve appears truncated, similar to that with robot-assisted laparoscopic prostatectomy.**

INTRODUCTION

THE BENEFITS OF laparoscopic total nephrectomy are well known, and laparoscopic nephrectomy is widely performed. Applying laparoscopy to nephron-sparing surgery can dramatically reduce patient morbidity without compromising oncologic effectiveness.[1,2] Despite its well-established benefits, laparoscopic partial nephrectomy (LPN) has not been universally adopted. The performance of LPN has been limited by technical challenges—namely, the advanced laparoscopic and reconstructive skill set required. This procedure, therefore, has been performed primarily only by highly experienced laparoscopic surgeons worldwide.

As evidenced by the broad acceptance and widespread performance of robot-assisted prostatectomy, the development of the daVinci surgical system (Intuitive Surgical, Sunnyvale, CA)

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has enabled more urologists to overcome the challenges associated with complex laparoscopic reconstructive procedures.[3]

Recently, robot-assisted partial nephrectomy has been described as a technical approach to facilitate nephron-sparing surgery.[4–8] Robot-assisted laparoscopic partial nephrectomy (RLPN) has been performed at the University of California, Irvine, since December 2003. A fellowship-trained urologic oncologist (DKO) with experience in laparoscopic nephrectomy but limited (<10 patients during 7 years of practice) reconstructive laparoscopic experience, performed each of these procedures. In addition, the surgeon performing RLPN had performed greater than 200 robot-assisted laparoscopic radical prostatectomies.

We sought to compare this cohort with a contemporary group of consecutive patients who underwent standard LPN performed by two experienced laparoscopic surgeons (RVC, EMM) with more than 13 years' experience performing LPN.

PATIENTS AND METHODS

After obtaining approval from the Institution Review Board, we reviewed the medical records of 10 consecutive patients who had undergone 11 unilateral RLPNs (1 patient had bilateral synchronous tumors resected in a staged fashion) between December 2003 and January 2007 at the University of California, Irvine, because of a preoperative diagnosis of renal-cell carcinoma. We compared these records with those of 11 consecutive patients undergoing 12 (one patient had two unilateral tumors) standard LPNs (between March 2005 and December 2006). We chose to review the most recent LPNs and compare them with the first cohort of RLPNs because this would represent one surgeon's (DKO) initial experience with a new procedure (RLPN) and match it with the experienced laparoscopic surgeons' (RVC, EMM) most recent patients, to provide a rigorous comparison group for this new procedure.

Parameters analyzed included age, tumor size, location, total procedure time, complications (namely, intraoperative, delayed postoperative hemorrhage, urinary extravasation), estimated blood loss, postoperative hematocrit, warm ischemia time, positive margin rate, tumor-free margin, and hospital stay. Tumors were classified as endophytic if they were completely intraparenchymal with no renal surface contour disturbance, mesophytic if 50% or more of the tumor was deep to the line of the renal capsule, and exophytic if more than 50% of the tumor was external to the line of the renal capsule.

Our technique for RLPN and standard LPN, respectively, follows.

Technique: RLPN

The patient is placed in the full flank position and secured with the operating table partially flexed. Pneumoperitoneum is achieved with a Veress needle inserted lateral to the rectus muscle at the level of the umbilicus. Once established, a 12-mm visual obturator port is passed into the peritoneal cavity. Next, an 8-mm robotic port is placed in the midclavicular line just below the costal margin, and a second 8-mm port is placed in the anterior axillary line also at the level of the umbilicus. These ports should be at least 8 cm apart to avoid clashing of the robotic arms, although the robot is not docked at this time.

Standard laparoscopic dissection ensues. The colon, spleen, and pancreas on the left are mobilized until the gonadal vein is identified; on the right, the colon, liver, and duodenum are mobilized until the inferior vena cava (IVC) is identified. A fourth port is placed two fingerbreadths superior and medial to the anterior superior iliac spine. This is a 12-mm assistant's port and facilitates passage of sutures, passage of Surgicel (Ethicon EndoSurgery, Cincinnati, OH) bolsters, application and removal of laparoscopic vascular bulldog clamps, and suction/irrigation of the operative field. A fifth port, 5 mm, can be placed in the midaxillary line at the level of the umbilicus to permit argon beam coagulation of the renal parenchymal surface.

For right-sided excisions, an additional 5-mm port can be placed just below the xiphoid in the midline or at the pararectus line subcostal to enable liver retraction for exposure of the renal hilum; the liver retraction is also essential during excision of right upper-pole renal masses (Fig. 1).

At this point, the daVinci robot is docked. Precise dissection along the gonadal vein on the left and along the anterior surface of the IVC on the right, using a hook electrode, allows the renal vein to be identified. This is then dissected to enable unencumbered placement and removal of the vascular clamp. On the left side, the gonadal vein is ligated, if necessary, to identify the renal artery, which is also dissected to allow application of the bulldog clamps. The anterior surface of the Gerota fascia is then incised until the renal capsule is seen.

The kidney is then uncloaked from within the Gerota fascia, with the exception of the fat left on the tumor surface. The peritumor renal capsule is scored either with the argon beam coagulator or the hook. The hook is exchanged for cold robotic scissors. Intraoperative ultrasonography is optional at this point to allow the surgeon to gauge the depth of the excision. A 6-inch 4-0 polyglactin suture on an RB-1 needle with a LapraTy clip (Ethicon EndoSurgery, Cincinnati, OH) on the free end and a 6-inch 1-0 polyglactin suture on a CT-1 needle with a LapraTy

A B

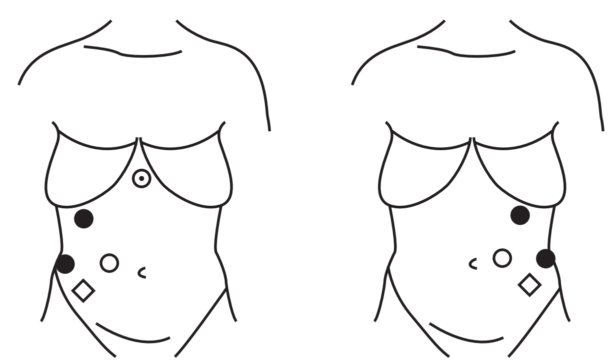

FIG. 1. Port site placement for right (**A**) and left (**B**) robot-assisted laparoscopic partial nephrectomy. Clear circles =12-mm camera port; doughnut = 5-mm port for liver retraction; black circles = 8-mm robot ports; clear diamond = 12-mm assistant port. An additional 5-mm port is placed in the midaxillary line at the level of the umbilicus for suction and argon beam coagulation (not shown).

clip on the free end are placed in the abdomen and passed into the abdominal wall in an easily accessible location; two 1-inch Surgicel bolsters are placed in the abdomen within easy reach. Mannitol, 12.5 g, is administered intravenously before arterial occlusion.

The assistant then introduces a bulldog clamp (Klein Surgical, San Antonio, TX) and places its full length across the artery. A second bulldog vascular clamp may be placed on the vein according to surgeon preference. Renal vein flow is significantly decreased from pneumoperitoneum alone and, for this reason, may act as an intrinsic "clamp."[9] We do not place an externally applied vascular clamp as described below for standard LPN, because this would require an additional port and may interfere with the assistant's maneuverability.

The tumor is then excised with the cold scissors and placed on the spleen or liver for entrapment after renal reconstruction is completed. During tumor excision, the assistant provides intermittent suction and retraction to allow optimal visibility for the surgeon. The assistant then treats the cut renal parenchymal surface with the argon beam coagulator, being careful to avoid collecting system coagulation. This is followed by repair of any obvious caliceal entry points with a 4-0 polyglactin suture on an RB-1 needle with a LapraTy clip. These clips are useful in facilitating the reconstruction and limiting warm ischemia time that may otherwise be prolonged if several knots were tied instead.[10] Large renal vessels may also be secured with figure of eight sutures.

A layer of Floseal (Baxter Inc., Irvine, CA) is then applied to the defect followed by Surgicel bolsters and simple bolstering sutures using 1-0 polyglactin on a CT-1 needle that are spaced approximately 1-cm apart. The second LapraTy clip is placed onto this suture such that adequate cinching of the renal parenchyma achieves tamponade.

A second layer of Floseal is applied; Tisseel (Baxter Inc., Irvine, CA) covering of the repair is optional. The vascular clamps are then removed. A closed suction drain is placed in the retroperitoneum along the paracolic gutter.

Technique: Standard LPN

The laparoscopic dissection is identical to the previously described robotic approach, albeit without the need for the 8-mm robotic ports that are replaced by standard 12-mm nonbladed ports. Other exceptions are that for wedge resections, the harmonic scalpel (Ethicon EndoSurgery, Cincinnati, OH) is used to excise the tumor, and for a true polar partial nephrectomy, we use the Ligasure device (Valleylab, Boulder, CO).

In addition, it is our preferred technique to use an externally applied laparoscopic vascular Satinsky clamp, placed through a midline or pararectus, subumbilical port. This achieves reliable and complete en-bloc occlusion of the renal hilum.

For most patients, the hilar dissection is limited to identifying the anterior surface of the vein, the inferior surface medial to the gonadal insertion, the superior surface medial to the adrenal vein, and the posterior body wall. This obviates separation of the artery and vein and visually ensures accurate and safe placement of the clamp. If en-bloc clamping of the renal hilum is deemed to be not feasible, the renal artery is dissected and a laparoscopic bulldog clamp is applied. Also, instead of an RB-1 needle, an SH needle is used with 2-0 polyglactin to close the collecting system in a running fashion, with the suture secured with LapraTy clips at either end. A closed suction drain is placed along the paracolic gutter in select cases, based on surgeon preference.

With regard to the assistant surgeons, for LPN a laparoscopy and endourology fellow routinely assisted the laparoscopic surgeon and, in some cases, a junior resident also assisted. For the RLPN patients, the robotic surgeon was assisted by a chief resident and, for some cases, a laparoscopy and endourology fellow also assisted. In both groups, the primary surgeons performing the critical aspects of the dissection (ie, the renal mobilization and the vascular dissection and isolation, the excision of the tumor, and renal reconstruction) were the laparoscopic surgeon and the robotic surgeon (including the preparatory laparoscopic dissection) for LPN and RLPN, respectively.

In each technique, whether or not the collecting system was been visibly breached, central sutures were placed to not only close a potential entry point but also to control the larger infundibular and pericaliceal vessels.

RESULTS

The mean age of the patients treated was 54 years in the LPN group and 53.2 years in the RLPN group. The mean tumor size was 2.3 cm (range 1.7–6.2 cm) in the LPN group, and 3.1 cm (range 2.5–4 cm) in the RLPN group. In the LPN group, there was one endophytic, two mesophytic, and nine exophytic tumors, whereas in the RLPN group, there was one endophytic, three mesophytic, and seven exophytic tumors. In the RLPN group, all tumors were clinically T_{1a}, whereas in the LPN group, there were 10 T_{1a} and 1 T_{1b} tumors.

There was no difference in blood loss, drop in hematocrit, total operative time, and warm ischemia time between the two groups. The mean total procedure time was 289.5 minutes (range 145–369 min) in the LPN group and 228.7 minutes (range 98–375 min) in the RLPN group ($P = 0.102$). The mean estimated intraoperative blood loss was 198 mL (range 75–500 mL) in LPN group *v* 115 mL (range 25–300 mL) in the RLPN group ($P = 0.169$).

The mean fall in postoperative hematocrit was 6.4% in the LPN group *v* 4.24% in the RLPN group ($P = 0.075$). In neither group was there bleeding from the resection site on release of the vascular clamps. The mean warm ischemia time was 35.3 minutes (range 15–49 min) in the LPN group and 32.1 minutes (range 30–45 min) in the RLPN group ($P = 0.501$).

There were no final true positive margins in either of the groups. One patient in the LPN group had a positive margin that was occurred secondary to fracturing of the tumor during extraction. There was a rim of normal renal parenchyma on the cut resection surface. However, along the line of fracture, which was through the tumor itself, microscopically the margin was positive, despite there being no contact of this "margin" with the cut renal resection bed. The surgeon felt that this split in the tumor's surface likely occurred during extraction of the tumor when it was already in the entrapment sack; this occurs when the extraction site incision is not sufficiently generous to allow the specimen to be extracted with little effort. The mean tumor-free margin was 2.9 mm for LPN and 2.1 mm for RLPN ($P = 0.385$).

There was one complication in the RLPN group, a postoperative hemorrhage necessitating hand-assisted laparoscopic reexploration. The patient received a total transfusion of 4 units of packed red blood cells. He was explored via hand-assisted laparoscopy, and the bleeding from the resection bed was controlled with argon beam coagulation and Floseal covered with Surgicel.

There was also one complication in the LPN group. This patient had urinary extravasation that necessitated placement of a percutaneous drain, an indwelling ureteral stent, and a nephrostomy tube. This patient had two tumors in the right kidney, the first necessitating an upper pole wedge excision and the second necessitating a lower-pole heminephrectomy.

The hospital stay was longer for the LPN than for the RLPN group (3.1 *v* 2 days; $P = 0.039$) (Table 1).

Follow-up imaging was available for all of the LPN patients

Table 1. Summary of Perioperative Data

	Robot-assisted laparoscopic partial nephrectomy	*Laparoscopic partial nephrectomy (6 degrees of hemostasis)*	P *values*
Age	Mean 53.2	Mean 54	
Sex	Male = 10 Female = 1	Male = 7 Female = 4	
Tumor size in cm (final pathology/greatest diameter)	3.1 (2.5–4)	2.3 (1.7–6.2)	
Location	Upper = 8 Lower = 3	Upper = 3 Mid = 3 Lower = 5	
Right/left	R = 4 L = 7	R = 4 L = 7	
Procedure time (min)	228.7 (98–375)	289.5 (145–369)	0.102
Type of partial	Wedge = 11	Wedge = 7 Complete = 4	
Warm ischemia time (min)	32.1 (30–45)	35.3 (15–49)	0.501
Change in creatinine (mg/dL)	0	0.1	0.452
Preoperative creatinine (before surgery <2 weeks) (mg/dL)	1.1	0.9	
Postoperative creatinine at discharge (mg/dL)	1.1	1.0	
Postoperative creatinine at 3 month follow-up (mg/dL)	1.2	1.1	
Intraoperative transfusion (units)	0.0	0.0	
Postoperative transfusion (units)	4	2	
Estimated blood loss (mL)	115.0 (75–500)	198 (25–300)	0.169
Fall in hematocrit (%)	4.2	6.4	0.075
Preop Hct	35.5	43.0	
Postop Hct (immediate)	31.6	36.6	
Discharge hemoglobin (g/dL)	10.8	12.1	
Discharge hematocrit (%)	31.7	35.5	
Positive margin rate at frozen section	Negative = 11 Positive = 0	Negative = 10 Positive = 1[a]	
Final tumor margin (mm)	2.1	2.9	0.385
Histology			
Clear cell	7	5	
Papillary	2	1	
Oncocytoma	0	3	
Other	2 (1 mixed epithelial and stromal tumor; 1 low grade collecting duct carcinoma)	2 (1 AML; 1 chromophobe)	
Postoperative hospital stay (days)	2.0	3.1	0.039

[a]Artifactually positive margin occurred because of fracturing of tumor during removal via small incision.
Hct = hematocrit; preop = preoperative; postop = postoperative; AML = acute myeloid leukemia.

and in 5 of 11 patients in the RLPN group. There were no recurrences observed in either group after a mean follow-up of 4.5 months (range 1–8 mos) and 16 months (range 4–37 mos) for the LPN and RLPN groups, respectively.

DISCUSSION

The daVinci robotic surgical system has revolutionized minimally invasive urologic laparoscopy as applied to prostatectomy. By providing a three-dimensional operating environment and instrumentation with two additional degrees of freedom, the daVinci surgical system appears to have dramatically reduced the learning curve for complex laparoscopic procedures. Even laparoscopically naïve but experienced open surgeons can become remarkably proficient in a technically challenging procedure such as robotic radical prostatectomy in as few as 12 patients.[3]

The first series of RLPN for small renal masses was reported by Gettman and associates[4] in 2004. Since then, there have been four other reports, three of which detail the New York University experience.[5–8] Our results closely approximate the previously published series. One patient in the robotic group was taken back to the operating room and explored via a hand-assisted laparoscopic approach to correct an early postoperative hemorrhage. His hospital stay was prolonged to 5 days as opposed to a mean of 1.7 days for the remaining 10 procedures. In our series, there were no conversions, whereas in the New York University series, among 12 patients, there were two conversions: One to a hand-assisted approach and one to an open approach.[6]

In the series of Kaul and colleagues,[8] like the present series, there were no conversions; however, one patient had urgent reexploration and nephrectomy. It is not stated in that report whether the nephrectomy was completed by standard laparoscopy, a hand-assisted approach, or an open approach; a 21-day hospital stay resulted.

Although LPN is now performed in a variety of centers with acceptable complication rates and oncologic outcomes, there appears to be a steep learning curve for this procedure even among experienced laparoscopic surgeons.[1,2,11] Indeed, early experience with this procedure was associated with excessive complications.[12] On the other hand, our experience suggests that the learning curve for RLPN is substantially shorter than that for LPN. Indeed, all operative parameters in our series were the same, despite the fact that one surgeon's initial 10 patients for RLPN were being compared with those of LPN performed by surgeons with a more than 60 LPN case experience. The only difference between the two groups was a shorter hospital stay in the RLPN group (LPN 3.1 days *v* RLPN 2 days; $P = 0.039$).

One potential roadblock to the widespread adaptation of RLPN to clinical practice, particularly in a community setting, is the need for an assistant experienced in laparoscopic surgery.[13] All of our RLPNs were performed with either an endourology fellow or laparoscopically trained senior resident as the assistant.

Another caveat to consider when contemplating the widespread application of this technique is the overall experience of the surgeon with robotic cases. RLPN is an advanced robotic procedure, and the surgeon must be facile with the technical aspects of robotic surgery and be comfortable applying these advanced techniques. To that end, we believe that this is not the robotic procedure for a console naïve surgeon to undertake early in his or her experience nor for a person who is not already skilled in open partial nephrectomy. Despite the small number of cases reported, we believe that the short-term technical aspects are sound and will likely not be altered even with a larger cohort; to be sure, additional follow-up data are needed to compare RLPN with LPN as well as with open partial nephrectomy results.

CONCLUSION

RLPN using the daVinci surgical system can be performed by a fellowship trained urologic oncologist with extensive experience with robotic radical prostatectomy; early results mirror those achieved by experienced laparoscopic surgeons performing standard LPN. These results further support the assumption that introducing a robotic interface facilitates surgeons with extensive experience in open and other robotic procedures (in this instance, open partial nephrectomy and robot-assisted radical prostatectomy) with the successful incorporation of advanced robotic procedures, such as partial nephrectomy, into their clinical practice.

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ABBREVIATIONS USED

IVC = inferior vena cava; LPN = laparoscopic partial nephrectomy; RLPN = robot-assisted laparoscopic partial nephrectomy.