Single surgeon's experience with laparoscopic versus robotic partial nephrectomy: perioperative outcomes/complications and influence of tumor characteristics on choice of therapy

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Introduction: *Laparoscopic (LPN) and robotic partial nephrectomy (RPN) may offer similar advantages for nephron-sparing surgery (NSS). We evaluated the perioperative outcomes and complications of LPN versus RPN and sought to evaluate if one technique may have more favorable outcomes over another based on tumor characteristics.*

Materials and methods: *All patients who underwent LPN and RPN by a single surgeon were retrospectively reviewed. The surgeon almost exclusively performed LPN from February 2009 to January 2011 and RPN from January 2011 to January 2012. Patient demographics, tumor characteristics, perioperative outcomes, short term renal functional data, and complications were reviewed. Operative time (OT), warm ischemia time (WIT), and estimated blood loss (EBL) were evaluated for each technique when tumor characteristics were divided by size, location, distance to collecting system, and overall tumor complexity based on nephrometry scoring.*

Results: *Of 39 laparoscopic cases and 30 robotic cases, there were no significant differences in perioperative outcomes, short term renal functional data, or complications between the two groups except for WIT which was shorter in the LPN group ($p = 0.006$). For medium complexity tumors, OT was less for LPN compared to RPN ($p = 0.04$); for high complexity tumors, EBL was reduced for RPN compared to LPN cases ($p = 0.003$). When tumor characteristics were individualized, LPN may be superior to RPN for WIT for small, anterior and exophytic tumors, and tumors located > 5 mm from the collecting system. LPN and RPN appear more equivocal for WIT in posteriorly located tumors. Reduced EBL may be a benefit with RPN for larger tumors.*

Conclusions: *Although WIT was less in patients undergoing LPN compared to RPN, perioperative outcomes and complications remain similar. RPN may be beneficial for approaching more difficult, posterior tumors, whereas LPN may be a better technique for WIT for simple, accessible renal tumors. Reduced EBL may be a benefit for RPN for highly complex tumors.*

Key Words: laparoscopic, partial nephrectomy, robotic

Introduction

In the 1980s and 1990s nephron-sparing surgery (NSS) was uncommon and restricted to special circumstances including solitary, bilateral tumors, genetically based tumors, and preexisting chronic kidney disease; however since the early 1990s, NSS has became a common modality for treatment of small renal masses on an elective basis.[1] At the same time, the introduction of laparoscopy with kidney surgery was developed.[2] In recent years NSS has become the gold standard for stage T1a renal tumors according to the American Urological Association guidelines and National Comprehensive Cancer Network.[3,4] Furthermore, minimally invasive approaches have become the emerging and prevailing

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technique for management of these renal masses. Although laparoscopic partial nephrectomy (LPN) has been the time-tested minimally invasive approach, it is technically challenging and limited to the use of experienced laparoscopic surgeons. With articulating arms, improved visualization and more precise control, robotic partial nephrectomy (RPN) has allowed for more facile and controlled tumor excision and renorrhaphy with an attenuated learning curve suggested at approximately 10-25 cases as opposed to 200 cases for LPN.[5-7] In this study we sought to retrospectively evaluate the perioperative outcomes and complications of LPN versus RPN from one surgeon's experience and evaluate if one technique demonstrates more favorable outcomes over another based on tumor characteristics.

Materials and methods

Study design and statistical analysis

Following institutional board review approval, all patients who underwent LPN and RPN by a single surgeon were retrospectively reviewed from February 2009 to January 2012. The surgeon almost exclusively performed LPN from 2009 to January 2011 and performed RPN from January 2011 to January 2012. Three RPN were performed prior to 2011. Regarding the surgeon's experience, prior to this study, the surgeon performed approximately 250 laparoscopic partial nephrectomy cases at a different institution. Additionally, the surgeon performed over 1000 laparoscopic radical prostatectomies prior to the advent of the robot. The surgeon adopted the robotic technique and since has performed approximately 1000 robotic prostatectomies. This led to his decision to perform robotic partial nephrectomies exclusively from January 2011 to the present.

Patient demographics, tumor characteristics, perioperative outcomes, short term renal functional data, and complications were reviewed between the two groups. Estimated glomerular filtration rate (eGFR) was estimated using the Modificaton of Diet in Renal Disease (MDRD) equation.[8] Average decrease in eGFR was calculated by preoperative eGFR minus postoperative eGFR on postoperative day 2 given the disparity in data at more remote follow up visits. Operative time (OT), warm ischemia time (WIT), and estimated blood loss (EBL) were evaluated for each technique when tumor characteristics were divided by size, location, distance to collecting system, and overall tumor complexity. Tumors were classified as endophytic if completely intraparenchymal, mesophytic if < 50% of the tumor extended to the renal capsule and exophytic if more than 50% of the tumor extended beyond the renal capsule. Nephrometry scoring was performed to evaluate overall tumor complexity.[9] A student's t-test or Fisher's exact test was used to compare each technique based on data characteristics. A two-sided p value of less than 0.05 was considered significant.

Surgical technique

The techniques for LPN and RPN were performed similarly. The surgeries were all performed via a transperitoneal approach. No laparoscopic cases were performed with hand assistance. A laparoscopic ultrasound was intermittently used to identify the margins of the renal mass, especially for endophytic or mesophytic tumors. The renal artery was almost exclusively clamped with two laparoscopic bulldog clamps for both techniques. Rarely the right renal vein was also clamped for right-sided cases if a short right renal artery was present. Early unclamping was not utilized for either technique due to surgeon preference. The collecting system and renal parenchyma were oversewn in two layers using a 2-0 monocryl suture with absorbable clips (Lapra-Ty, Ethicon, Cincinnati, Ohio, USA). The use of a cellulose-rolled bolster was determined by the ability to bring the cortical defect together and was determined on a case-by-case basis. All LPN cases except for three required the use of a bolster, whereas only nine RPN cases required the use of a bolster. A Jackson-Pratt (JP) drain and Foley catheter were placed in all cases. Postoperatively, it was routine for all patients to have a JP drain creatinine sent for analysis. Foley catheters were routinely removed on postoperative day 1, and the JP drains were typically removed 1 day later.

Results

A total of 69 patients were evaluated with 39 cases performed laparoscopically and 30 cases performed robotically. There were no significant differences between the two groups regarding age, gender, race, body mass index (BMI), and American Society of Anesthesiology (ASA) score, Table 1. There were also no differences in tumor size, location, and mean distance to the collecting system, Table 2. Pathologic characteristics were similar except for Fuhrman grade. Positive margin status was similar with 11% in LPN and 7% in RPN (p = 0.61). In the four LPN cases with positive margins, two were at the parenchymal margin, and one was at the capsular margin which is likely not a true positive margin. The fourth

TABLE 1. **Patient demographics**

	LPN (n = 39)	RPN (n = 30)	p value
Mean age (years)	57 ± 11	59 ± 11	0.49
Males/females	29/10	17/13	0.13
Caucasian race	34 (87%)	25 (83%)	0.66
Mean BMI (kg/m^2)	29 ± 5	30 ± 7	0.85
Mean ASA score	2	2	0.99

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy; BMI = body mass index; ASA = American Society of Anesthesiology

one had a positive margin, but subsequent radical nephrectomy due to primary neuroectodermal tumor pathology was negative for malignancy in the final specimen. In the two RPN cases with positive margins, one was at the parenchymal margin, and one was at the capsular margin. There were no significant differences in perioperative outcomes, short term renal functional data, or complications between the two groups except for WIT which was less in the LPN group at 20.4 minutes compared to 24.9 minutes in the RPN group (p = 0.006), Table 3. Although not statistically significant, LPN trends toward reduced OT (with mean of 119.7 min for LPN versus 135.5 min for RPN, p = 0.08) but greater EBL (with mean of 235 mL versus 152 mL for RPN, p = 0.19). Of note, of the two conversions of laparoscopic partial to radical nephrectomies, one case was due to multi-focal satellite lesions detected intraoperatively which was felt to be better served by full resection. The other case was

TABLE 2. **Tumor characteristics**

	LPN (n = 39)	RPN (n = 30)	p value
Mean size (cm)	3.1 ± 1.2	3.2 ± 1.2	0.73
Left/right kidney	24/15	16/14	0.50
Location			
Upper pole	13 (33%)	6 (20%)	0.23
Mid pole	20 (51%)	15 (50%)	0.92
Lower pole	6 (15%)	9 (30%)	0.15
Exophytic	3 (8%)	4 (13%)	0.45
Mesophytic	22 (56%)	13 (43%)	0.29
Endophytic	14 (36%)	13 (43%)	0.54
Mean distance to collecting system (mm)	5.0 ± 5.0	3.9 ± 5.2	0.41
Pathology			
T1a	23 (59%)	18 (60%)	0.93
T1b	9 (23%)	8 (27%)	0.74
T2 or greater	4 (10%)	1 (3%)	0.28
Benign	3 (8%)	3 (10%)	0.74
Histology			
Clear cell	25 (64%)	21 (70%)	0.61
Papillary	7 (18%)	5 (17%)	0.83
Chromophobe	3 (8%)	1 (3%)	0.45
Oncocytoma	2 (5%)	1 (3%)	0.72
Neuroectoderm	1 (3%)	0 (0%)	0.38
Other	1 (3%)	2 (7%)	0.41
Fuhrman Grade			
1-2	20 (57%)	22 (81%)	0.04
3-4	15 (43%)	5 (19%)	0.04
Positive margins	4 (11%)	2 (7%)	0.61

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy

TABLE 3. **Outcomes**

	LPN (n = 39)	RPN (n = 30)	p value
Mean estimated blood loss (mL)	235 ± 278	152 ± 189	0.19
Mean warm ischemia time (min)	20.4 ± 6.1	24.9 ± 6.7	0.006
Mean operative room time (min)	119.7 ± 34.1	135.5 ± 36.4	0.08
Mean length of hospital stay (days)	2.7	2.7	0.99
No. of patients with preoperative eGFR < 60	9 (23%)	7 (23%)	0.98
No. of patients with postoperative eGFR < 60	15 (38%)	12 (40%)	0.90
Average decrease in eGFR	17.3 ± 12.4	11.0 ± 4.9	0.15
Average decrease in serum creatinine	0.4 ± 0.2	0.2 ± 0.2	0.09
Complications			
Conversion to radical nephrectomy	2 (5%)	0 (0%)	0.21
Postoperative urinary leak	0 (0%)	0 (0%)	0.99
Postoperative transfusion	2 (5%)	2 (7%)	0.79
Postoperative embolization due to hemorrhage	1 (3%)	2 (7%)	0.41
Postoperative dialysis	0 (0%)	1 (3%)	0.26
Follow up (months)	11.1 ± 11.4	5.0 ± 3.8	0.01

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy; eGFR = estimated glomerular filtration rate

initially accomplished with LPN but due to the final pathology of primary neuroectodermal tumor with positive margins, the decision was made to perform an open radical nephrectomy 2 months after the initial surgery. As expected, mean follow up was longer for LPN compared to RPN given the LPN cases were performed at an earlier date than the RPN cases (11.1 months versus 5.0 months, p = 0.01).

When using nephrometry scoring, there was no statistical significance for tumor complexity although there were more medium complexity LPN cases compared to RPN cases (62% versus 40% respectively, p = 0.08), Table 4. For medium complexity tumors, OT was less for LPN compared to RPN (p = 0.04), Table 5. For high complexity tumors, EBL was reduced for RPN compared to LPN cases (p = 0.003). When stratified by individual tumor characteristics, LPN may be superior to RPN for WIT for small ≤ 3 cm (p = 0.007), anterior (p = 0.0007), and exophytic tumors (p = 0.04), and tumors located ≥ 5 mm from the collecting system (p = 0.02). LPN and RPN appear equivocal for posterior-located tumors for WIT (p = 0.97). Reduced EBL may be a benefit with RPN for larger tumors > 3 cm in size (p = 0.008).

TABLE 4. **Nephrometry scoring**

	LPN (n = 39)	RPN (n = 30)	p value
Low complexity (4-6)	7 (18%)	8 (27%)	0.59
Medium complexity (7-9)	24 (62%)	12 (40%)	0.08
High complexity (10-12)	8 (21%)	10 (33%)	0.24

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy

Discussion

This study sought to evaluate the benefits of RPN compared to LPN. RPN may demonstrate advantages over LPN attributable to the ease of instrument maneuverability and improved visualization. The literature supports the assertion that a steeper learning curve exists for laparoscopy which may provide an additional advantage of robotic surgery even with the robot naïve surgeon.[10] The data comparing perioperative outcomes in RPN to LPN is conflicting and is likely dependent on the surgeon's experience with laparoscopy. Several studies have retrospectively compared LPN to RPN. Wang et al described a single surgeon experience in which OT, WIT and length of stay (LOS) were reduced with RPN compared to LPN with no difference in EBL or positive surgical margins.[11] Similarly, Peirorazio et al demonstrated decreased OT, WIT as well as decreased mean EBL with RPN versus LPN, and Delong et al showed shorter WIT but longer

TABLE 5. **Outcomes based on tumor complexity**

	LPN (n = 39)			RPN (n=30)			
Nephrometry score	**OT (mins)**	**WIT (mins)**	**EBL (mL)**	**OT (mins)**	**WIT (mins)**	**EBL (mL)**	**p value (OT, WIT, EBL)**
Low complexity	125.0	16.6	135.7	121.9	22.5	240.8	0.86, 0.11, 0.49
Medium complexity	115.8	20.8	254.6	145.3	23.8	132.0	0.04, 0.19, 0.28
High complexity	127.9	22.8	262.5	134.4	28.2	117.5	0.69, 0.08, 0.003

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy; OT = operative time; WIT = warm ischemia time; EBL = estimated blood loss

OT for robotic cases.[12,13] However, other retrospective studies have demonstrated non-inferiority of RPN with no significant differences between WIT, EBL, LOS or eGFR.[14,15] A prospective study followed patients assigned to either LPN or RPN and found decreased WIT in the RPN group with no statistically significant differences between OT, EBL, LOS, transfusion rate, positive surgical margins or post-operative decreases in eGFR.[16] One of the greatest anticipated benefits of the RPN approach includes the ability to achieve shorter ischemic times thereby preserving renal function. WIT greater than 25 minutes has been associated with worse outcomes and increased progression to stage IV CKD.[17] While decreases in WIT were not demonstrated for RPN in our initial study they remained below the critical threshold in both the LPN and RPN groups. The inconsistency in our findings demonstrating increased WIT with RPN is likely attributed to the surgeon's advanced experience with laparoscopy. In our study, the surgeon performed LPN consecutively before switching to the RPN approach providing the opportunity of time to gain additional experience in minimally invasive NSS. Additionally, while many of the previously citied studies were conducted with surgeons skilled in laparoscopy, the surgeon in our study may have been uniquely qualified to overcome the inherent technical challenges. In our circumstance, the surgeon was trained in the era of laparoscopy and likely is more comfortable with this method, whereas the overall number of robotic cases performed for kidney surgery is significantly less for this one individual. His comfort with the laparoscopic approach is demonstrated by the dramatically shorter LPN procedure time in our study with a mean of just 119.7 minutes compared to means from prior studies ranging between 156-289 minutes.[10-19] Another contributing factor which may explain the reduced WIT in laparoscopic cases is that there were more medium complexity cases and less high complexity cases compared to robotic cases, although not statistically significant.

Further decreases in WIT remain an achievable goal with modifications in technique although whether further decreases are clinically significant remains to be seen. Techniques to decrease WIT in RPN are being adopted with notable improvements. Specifically use of sliding-clip renorrhaphy in RPN has been described obtaining decreases in WIT as have early unclamping techniques which reduce ischemic time compared to bulldog clamps.[18] Aron et al demonstrated decreased WIT in LPN with an early unclamping technique indicating that technique is an important modifier in the perioperative outcomes associated with either surgical approach.[15] In spite of these studies, the surgeon in our study has not adopted the early unclamping technique due to the theoretical risk of additional blood loss. It is also relevant to note that the complexity of renal masses appears to have a greater effect on WIT with the laparoscopic approach versus robotic assisted approach.[18] Renal masses characterized by a RENAL nephrectomy score ≥ 7 demonstrated a significant conversion rate to radical nephrectomy with LPN compared to RPN.[19] When our cohort was divided based on nephrometry score, laparoscopic cases had a shorted OT for medium complexity cases, although it is somewhat unclear as to why this was the case. However it may be more apparent that robotic cases may allow for reduced EBL for the highest complexity cases due to control of movements with the robot. More interestingly were the findings when tumor characteristics were individualized. Although WIT was less in LPN compared to RPN with this surgeon for all cases, perhaps RPN may be more beneficial in more difficult to access complex renal masses.

In the current era of healthcare reform and cost-consciousness it is important to appreciate the inherent costs associated with the LPN and RPN approaches. RPN is associated with a cost premium in both actual and ideal utilization scenarios using perioperative and hospitalization costs, however the long term cost-

saving effects of potentially improved postoperative outcomes has not been assessed.[20]

There are several limitations to our study. This study was conducted in a retrospective fashion, and our sample size is relatively small due to the surgeon adopting the robotic technique for renal surgery. The one advantage of the design of the study is that the laparoscopic cases were performed in a set amount of time followed by the robotic cases therefore minimizing selection bias. However, because the surgeon's practice is primarily a referral center, our follow up data was limited given most patients return to their local urologists or practitioners for further follow up. It is our practice to see patients back for a 2 week postoperative visit followed by a 6 month visit for cancer surveillance. Although most patients return for this 6 month visit, most patients choose to have their follow up imaging and evaluation performed locally thereafter. Another constraint of this study is that as stated before, the surgeon was trained primarily in laparoscopy and later adopted robotic surgery. Therefore, the applicability of this study to the average surgeon may be limited. A surgeon who has no biases toward laparoscopy versus robotics may experience more benefits of the robot regarding WIT, OT, and EBL. All surgeons may experience that the robot will be beneficial for complex renal masses that are difficult to access due to location compared to traditional laparoscopy. A multi-institutional prospective study would likely be useful in validating this observation.

Conclusions

Although WIT may be decreased in patients who undergo LPN compared to RPN in one surgeon's experience, short term renal functional outcomes remain similar as well as other perioperative outcomes and complications. With improved articulation of robotic surgery, RPN may be more beneficial for approaching difficult, posterior-located tumors, whereas LPN may be a better technique for WIT for simple accessible renal tumors with an experienced laparoscopic surgeon. For overall highly complex cases based on nephrometry score, RPN may be beneficial for reducing blood loss. Prospective studies are warranted to better understand if one technique may prevail over another in surgical and oncologic outcomes. □

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