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Robot Assisted Partial Nephrectomy: A Large Single Institutional Experience

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Abstract

Objectives—Nephron-sparing surgery is an established treatment for patients with small renal masses. The laparoscopic approach has emerged as an alternative to open nephron-sparing surgery, but it is recognized to be technically challenging. The robotic surgical system may enable faster and greater technical proficiency, facilitating a minimally invasive approach to more difficult lesions while reducing ischemia time. We report experience with 100 robot assisted partial nephrectomy (RAPN) operations performed at our institution.

Methods—100 RAPN operations were performed for suspicious solid renal lesions over 21 months. Clinicopathologic variables, nephrometry scores, operative parameters, and renal functional outcomes were prospectively recorded and analyzed.

Results—Median tumor size was 2.8 cm (range 1.0 to 8). Nephrometry scores of resected lesions were low in 47.9% of patients, medium in 45.7%, and high in 6.4% patients. 46.8% of patients had tumors > 50% intraparenchymal, and 61.7% had tumors <7mm from the renal sinus or collecting system. 17.0% were touching a first order vessel in the renal hilum. Mean warm ischemia time was 25.5 minutes (range 0 to 53). Mean change in postoperative GFR improved 6.32 ml/min/1.73m² (range −41.9 to 68.9). Histology was renal cell carcinoma in 81% (87/107) of tumors. There were 5 microscopically positive margins on final pathology (5.7%). Major and minor complication rates were 6% and 5%, respectively. There were 2 conversions to open surgery.

Conclusions—RAPN appears to be a safe and technically feasible minimally invasive approach to nephron-sparing surgery even in more complex cases, with acceptable pathologic and renal function outcomes.

Keywords

carcinoma; renal cell; robotics; nephrectomy; laparoscopy

Introduction

It is well established that nephron-sparing surgery for small renal masses achieves excellent functional and oncologic outcomes.¹ Laparoscopic partial nephrectomy combines the benefits

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of nephron-sparing surgery with the shorter-term advantages of laparoscopic techniques.² Unfortunately, the technical challenges posed by laparoscopic partial nephrectomy deter many urologists from performing this operation. Indeed, there is some concern that laparoscopic radical nephrectomy, a less technically challenging operation, has been overused for small renal masses in lieu of nephron-sparing surgery.^{3,4}

Recent guidelines released from the AUA based on a systematic review of the literature regarding management of the T1 renal mass reiterate the overutilization of radical nephrectomy and highlight the greater perioperative risks associated with minimally invasive nephron-sparing approaches.⁵ Moreover, they underscore that clinical decision making as to how best approach a given renal mass in a particular patient is overly subjective and that in the absence of level I evidence, physician treatment recommendations are subject to training patterns, biases, comfort levels, and individual experiences.⁶

Urologists are increasingly familiar with robotic techniques, as approximately 60% of radical prostatectomies in the United States were performed robotically in 2007.⁷ This technical familiarity, as well as the wristed robot instrumentation, may enable faster and greater technical proficiency for minimally invasive nephron-sparing surgery. Early small single-institution series have demonstrated feasibility of this approach.^{8–10} More recently data from several smaller series have been updated and re-published in a combined multi-institutional experience of robotic partial nephrectomy in 129 patients, which currently represents the largest cohort to date.¹¹

Here, we report pathologic, perioperative, and renal functional outcomes from the first 100 robot assisted partial nephrectomy (RAPN) operations performed at our institution. Additionally, we apply an objective renal mass scoring system (nephrometry6) to characterize and objectify the complexities of the lesions resected.

Materials and methods

From August 2007 until April 2009, 100 planned RAPN operations were performed at our institution with the da Vinci S surgical system (Intuitive Surgical, Sunnyvale, CA). The procedures were performed by 4 different surgeons. Preoperative workup included serum creatinine measurement as well as abdominal imaging with contrast based computed tomography or magnetic resonance imaging. An institutional kidney cancer database is maintained prospectively in accordance with Institutional Review Board guidelines and contains demographic, operative, and follow-up information on over 1700 consecutive kidney cancer patients treated at our institution. In addition, nephrometry scores have been calculated and maintained prospectively since October 2008.

A 3-arm technique was employed by all surgeons. Measurements from umbilicus to lower pole, renal hilum, upper pole, and mass were obtained from the pre-operative imaging. Port location was tailored to the location of the mass and renal hilum (figure 1). Specifically, the camera port was placed approximately 4–6 cm lateral to midline at the vertical midpoint between the renal hilum and the mass. The 8 mm robotic arm ports were placed laterally 8 cm from the plane of the camera. A 12 mm assistant port was placed in the plane between the camera and the inferior robotic arm to facilitate access to both the hilum and tumor. An additional 5 mm port was placed when needed, especially for right-sided tumors requiring liver retraction.

Exposure of the entire kidney, dissection of the renal hilum, and identification of the tumor was performed robotically in all cases. Intraoperative ultrasound with TilePro projection onto the console screen was used to confirm the margins of the mass and guide scoring the renal capsule with electrocautery or sharp dissection. Bulldog clamps were used for arterial clamping. Venous occlusion was performed at the surgeon's discretion. The tumor was excised

with round-tipped scissors. Collecting system defects were repaired with intracorporeal suturing. The base of the resection was biopsied and then coagulated with an argon beam coagulator. Renal parenchymal reconstruction was performed with 2-0 polyglactin suture over rolled oxidized cellulose bolsters, secured with Lapra-Ty clips (Ethicon EndoSurgery, Cincinnati, OH). Sutures were cut and removed after reperfusion to minimize warm ischemia time.

Assessment of margin status was based on both intraoperative frozen-section and final pathology. All patients with positive intraoperative margins underwent immediate re-resection to negative margins. These patients are considered to have negative final margin status. Patients with negative intraoperative biopsies but tumor present at the inked margin on final pathology are considered to have a positive final margin status. All patients have undergone follow-up cross-sectional imaging every 6 to 12 months postoperatively to assess for recurrence.

Functional renal preservation was assessed through comparison of pre-operative and post-operative glomerular filtration rate (GFR), which was calculated using the Modification of Diet in Renal Disease formula. Because not all patients underwent laboratory testing at short-term follow-up, serum creatinine on the day of discharge was used as the post-operative value in GFR calculations. All patients underwent contrast based imaging within 2 weeks after surgery to assess for flow, function, and leak from the operated renal unit.

Complications within 30 days of the procedure were recorded prospectively and graded according to the Clavien classification system.¹² Urine leak was defined as a radiographically proven extravasation of urine and/or elevation of drain fluid creatinine greater than twice serum creatinine at two-week follow-up. Ileus was defined as need for placement of nasogastric tube.

Results

Patient demographics, tumor characteristics, operative outcomes, and pathologic results are detailed in Table 1. Of the 100 planned procedures, 98 RAPN operations for 107 masses were completed robotically, as 7 patients underwent the synchronous resection of multiple ipsilateral tumors. Two attempted RAPN operations required conversion to open procedures. In one instance conversion was necessary due to ventilatory issues with pneumoperitoneum; in the other severe hepatomegaly and intraoperative biopsy proven cirrhosis prevented sufficient liver retraction to expose a large posterior upper pole tumor.

Nephrometry scores of resected lesions were low (4, 5, or 6) in 45/94 patients (47.9%), medium (7, 8, or 9) in 43/94 patients (45.7%), and high (10, 11, or 12) in 6/94 patients (6.4%). 46.8% (44/94) had an endophytic score of 2 or more to indicate the tumor was greater than 50% intraparenchymal, and 61.7% (58/94) had a nearness score of 2 or more to suggest the tumor was less than 7mm from the renal sinus or collecting system. 16 of 94 patients (17.0%) were given a hilar designation, meaning they were touching first order vessel in the renal hilum. Median tumor size was 2.8 cm (range 1.0 – 8.0 cm). 88% (86/98) of procedures were performed with renal artery clamping. Warm ischemia ranged 10 – 53 minutes with a median ischemia time of 25.5 minutes. Median OR time was 203 minutes. Mean estimated blood loss was 127 ml (range 50 – 800 ml). There were no intra-operative transfusions, although three patients (3%) received post-operative transfusions. One patient had an intraoperative blood loss of 800 ml; another patient had significant subcutaneous bleeding at a port site in the recovery room, requiring additional stitches for hemostasis; a third patient was discharged uneventfully but returned with a bleeding pseudoaneurysm that required 5 units of packed red blood cells and subsequent angioembolization.

Preoperative GFR ranged from 33.6 to 164.1 ml/min/1.73m². The mean post-operative change in GFR was 6.32 ml/min/1.73m², with a range of –41.9 to 68.9. The average change in GFR

was not statistically significant or related to ischemia time. 4 patients were treated asynchronously with RAPN for bilateral tumors. The average change in GFR for these patients from presentation until discharge after the second procedure was an increase of 4.2 ml/min/1.73m². In the seven patients treated for multifocal masses, median warm ischemia time was 25 minutes and the mean change in GFR was 6.0 ml/min/1.73m².

87 of the 107 tumors were malignant. The three collecting duct type RCC masses were from a single patient. There were 5 microscopically positive margins on final pathology (5.7%). The incidence of positive margins was not related to individual surgeon experience. All patients with positive final margin status elected surveillance over reoperation. No patient in this series has developed radiologic evidence of tumor recurrence over a mean follow-up of 12.7 months (median 12, range 5 to 25).

Complications are detailed in Table 2 and scored using the Clavien classification system to objectify reporting.¹² One patient with a drug eluting cardiac stent went into a pulseless dysrhythmia due to myocardial infarction at the time of port site closure. This patient died during attempted coronary revascularization. There were 5 significant complications that required procedural intervention. 2 patients had evidence of urine leak at initial follow-up.

Discussion

The primary goals of nephron-sparing surgery are complete tumor extirpation and maximal renal functional preservation. Therefore, any novel approach to nephron-sparing surgery must first meet these requirements before improving secondary outcomes, such as blood loss, post-operative pain, and length of stay.

The frequency of positive margins in nephron-sparing surgery varies in the literature. The largest open partial nephrectomy series included 1390 procedures and identified a 5.8% positive margin rate.¹³ The larger laparoscopic partial nephrectomy series in the literature have demonstrated positive margin rates of 1.8 to 3.5%.^{14–16} To our knowledge the present study represents the largest published single-institution RAPN series to date. Our positive margin rate was 5.7%. Other series of RAPN (Table 3) have reported positive margin rates from 0 to 10%.^{8–11,17–23} Undoubtedly, the technical approach to nephron-sparing surgery is not the only factor that affects positive margin rates. Surgeon tolerance for narrow margins, use of intraoperative ultrasound, and tumor extraction technique for minimally invasive approaches may all affect the interpretation or presence of tumor at the margins. Although several studies have noted that microscopic margin status does not predict recurrence or metastatic progression, complete tumor extirpation remains an essential goal of nephron-sparing surgery.^{13,24} Nonetheless, these short-term results suggest that a robotic approach to nephron-sparing surgery does not compromise oncologic principles. Additionally, the complexities of renal masses excised by minimally invasive techniques have never been adequately objectified making comparisons between series impossible. Here we have included nephrometry scores of all patients undergoing robotic partial nephrectomy in an attempt to provide the reader and subsequent investigators the most clear indication of the complexity of our cohort.

Several factors have been associated with deterioration of renal function following partial nephrectomy. These include older age, male sex, lower preoperative glomerular filtration rate, solitary kidney, larger tumor size, increased ischemia time, increased resection size, and postoperative complications.²⁵ In the present RAPN series, there was no significant change between median pre- and postoperative GFR. Because all but one patient had two functional renal units, the excellent preservation of renal function may be related to the contribution of a contralateral kidney.²⁶ Still, it is worth noting that GFR, on average, was unchanged in the four patients who underwent asynchronous, bilateral RAPN procedures. The preservation of

renal function in this subpopulation suggests that compensation by a contralateral kidney may be minimal. As a whole, the renal functional outcomes in this series demonstrate that nephron preservation with the RAPN technique is acceptable. In fact, when compared to the largest reported laparoscopic partial nephrectomy series,² tumor sizes were comparable (median 2.8 vs. mean 2.7) but warm ischemia time was improved with RAPN (median 25.5 min vs. mean 30.7).²

With regard to safety, the laparoscopic approach has been associated with increased morbidity compared to traditional open nephron-sparing surgery. The recent systematic review published as part of the AUA guidelines on the treatment for stage I renal tumors identifies a nearly 50% increase in “major complication” in laparoscopic partial nephrectomy compared to an open approach (9.0% versus 6.3%).⁵ Likewise, in a multiinstitutional review of 1800 laparoscopic and open partial nephrectomies, Gill et al. identified an approximately 2-fold increase in intra-operative and post-operative complications with the laparoscopic approach.² Of the patients undergoing planned laparoscopic partial nephrectomy in that series, 2.1% required conversion to open surgery, and 0.9% required conversion to radical nephrectomy. Our experience with RAPN conversion is similar, with 2% conversion to open surgery and 1% conversion to radical nephrectomy. Moreover, Gill et al. identified a 5.8% overall post-operative transfusion rate and a 4.2% hemorrhage rate (defined as 3 or more units of blood transfused or intervention for bleeding) in their laparoscopic partial nephrectomy population. Our bleeding complications compare favorably, with a 3% overall transfusion rate and 2% hemorrhage rate following RAPN. In addition, that series reported a 3.1% urinary leak rate for laparoscopic partial nephrectomy; we experienced a 2% leak rate with RAPN. Our nonurologic complications, OR time, incidence of loss of kidney, and length of stay likewise compare favorably with the laparoscopic partial nephrectomy data.

The present series suggests that RAPN is an oncologically sound approach with acceptable immediate nephron-sparing outcomes. Greater follow-up will be needed to confirm durable renal preservation and oncologic efficacy. Moreover, longer warm ischemia times for more complex tumors have been felt to be a limiting factor preventing a minimally invasive approach to nephron-sparing surgery. Although an earlier report by Caruso et al concluded that RAPN “does not offer any clinical advantage over conventional laparoscopic nephrectomy,”^{10,18} we believe robotic assistance facilitates a minimally invasive approach to nephron-sparing surgery with acceptable ischemia times for more challenging tumors. This contention has recently been advocated by Benway et al. based on a multi-institutional dataset comparing 129 RAPNs to 118 laparoscopic partial nephrectomies.¹¹ Larger comparative studies of open partial nephrectomy, laparoscopic partial nephrectomy, and RAPN are needed to determine optimal utilization of each technique. Furthermore, utilizing a uniform scale such as nephrometry to grade anatomic complexity of renal tumors would facilitate comparison of outcomes with these controlled for tumor difficulty.⁶

Conclusions

RAPN appears to be a safe and technically feasible minimally invasive approach to nephron-sparing surgery. Pathologic and functional results are comparable to open and laparoscopic surgery. Follow-up data is needed to assess the oncologic efficacy of this technique. Objective measures of tumor complexity are necessary for meaningful data comparisons of open and minimally invasive approaches.

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Figure 1.
The large black circle represents the 12 mm camera port; smaller solid circles represent 8 mm robotic arm ports; dotted circles represent possible locations of 12 and 5 mm assistant ports.

Table 1

Patient demographics and operative outcomes

Parameter	Value
<i>Patient factors</i>	
RAPN procedures, n	100
Median age, years (range)	55 (25 – 85)
Sex, n	
Male	68
Female	32
ECOG performance status 1 or greater	13 (13%)
ASA score 3 or greater	25 (25%)
Median Charlson Comorbidity Index score (range)	0 (0–5)
Mean score	0.81
<i>Tumor characteristics</i>	
Side, n	
Left	42 (42%)
Right	58 (58%)
Asynchronous bilateral procedures, n	4 (4%)
Patients with multiple ipsilateral tumors, n	7 (7%)
Median radiographic tumor size, cm (range)	2.8 (1.0 – 8.0)
<i>Nephrometry⁶ Scores:</i>	
	<u>1</u> <u>2</u> <u>3</u>
R (size criteria)	82 (87.2%) 11 (11.7%) 1 (1.1%)
E (endophytic/exophytic)	50 (53.2%) 41 (43.6%) 3 (3.2%)
N (nearness to sinus or calyx)	36 (38.3%) 9 (9.6%) 49 (52.1%)
A (anterior or posterior)	A=58 (61.7%) X=7 (7.4) P=29 (30.9%)
L (location relative to polar line)	32 (34.0%) 26 (27.7%) 36 (38.3%)
Hilar designation	16 (17.0%)
Total Nephrometry Score:	4 7 (7.4%) 15 (16.0%)
	5 23 (24.5%)
	6 17 (18.1%)
	7

Parameter	Value
	8
	13 (13.8%)
	9
	13 (13.8%)
	10
	6 (6.4%)
	11
	0
	12
	0
<i>Perioperative outcomes</i>	
Median warm ischemia time, min (range)	25.5 (0 – 53)
Mean, min	25.5
Median Estimated blood loss, ml (range)	50 (50 – 800)
Mean, ml	127
Intra-operative transfusion	0
Conversion to open	2 (2%)
Median OR time, min (range)	203 (85 – 369)
Mean, min	206
Post-operative transfusion, n patients	3 (3%)
Mean pre-operative creatinine, mg/dl (range)	1.0 (0.5 – 1.7)
Mean pre-operative GFR, ml/min/1.73m ² (range)	83.4 (33.6 – 164.1)
Pre-op CKD stage III, IV or V	11 (11%)
Mean change creatinine, mg/dl (range)	0 (–0.6 – 0.5)
Mean change GFR, ml/min/1.73m ² (range)	6.32 (–41.9 – 68.9)
Median length of stay, days (range)	3 (1 – 7)
Mean, days	3.2
<i>Pathology</i>	
RCC, total n	87 (81.3%)
Chromophobe type	5 (5.7%)
Clear cell type	58 (66.6%)
Papillary type	21 (24.1%)
Collecting duct	3 (3.4%)
Benign, total n	20 (18.7%)
Angiomyolipoma	5 (25%)
Benign cyst	7 (35%)
Glomangioma	1 (5%)

Parameter	Value
Onco cytoma	7 (35%)
Negative margin status, n	82 (94.3%)
Re-excision	2 (2.3%)
Microfocal positive final margin	5 (5.7%)

Table 2

Complications, by Clavien grade

Grade V:
<ul style="list-style-type: none"> • death due to myocardial infarction during port site closure
Grade IV: none
Grade III:
<ul style="list-style-type: none"> • pulmonary embolism → IVC filter • perinephric collection → percutaneous drainage • delayed hemorrhage → IR embolization of pseudoaneurysm and 5 units PRBCs • ureterolithiasis causing urinary leak → ureteral stent • port site bleed → 2 units PRBCs and stitch placed at bedside
Grade II:
<ul style="list-style-type: none"> • stable post-operative anemia → 2 units PRBCs • pulmonary embolism → anticoagulation • c. difficile colitis → antibiotics • rhabdomyolysis → hydration and alkalinization • pyelonephritis → antibiotics
Urinary leaks:
<ul style="list-style-type: none"> • 1 secondary to ureterolithiasis (as above) managed with stent • 1 managed successfully with observation

Table 3

Published RAPN series

	Institution	RAPN (n)	Tumor size (cm)	OR time (min)	WIT (min)	EBL (min)	LOS (days)	Complications by Clavien grade (II-V)	Positive Margins (n)	Urine Leaks (n)	Conversions
Gettman et al ⁸	Mayo Clinic	13	3.5	215	22	170	4.3	none	1	NR	0
Kaul et al ⁹	Henry Ford	10	2	155	21	92	3.5	II: 1 III: 1	1	1	0
Caruso et al ¹⁰	New York University	10	1.95	279	26.4	240	2.6	III: 1	0	NR	1 to OPN 1 to hand assisted LPN
Rogers et al ¹⁷	National Institutes of Health	8	3.6	192	31	230	2.6	none	0	NR	NR
Aron et al ¹⁸	Cleveland Clinic	12	2.4	242	23	329	4.7	II: 2 III: 1	0	0	2 to LPN
Deane et al ¹⁹	UC Irvine	11	2.3	229	32.1	115	2.0	III: 1	0	NR	0
Ho et al ²⁰	Medical University Of Innsbruck, Austria	20	3.5	82.8	21.7	189	4.8	None	0	0	0
Wang et al ²¹	Washington University	40	2.5	140	19	136	2.5	II: 2 III: 1 undefined: 4 *	1	1	1 to OPN 1 to cryoablation
Michli et al ²²	Cooper University Hospital	20	2.7	142	28	263	2.8	II: 1 III: 1	0	NR	1 to OPN
Gong et al ²³	City of Hope	29	3.0	197	25	220	2.5	NR	0	NR	NR
Benway et al ¹¹	Multiple Institutions	129 [†]	2.9	189	19.7	155	2.4	II: 1 III: 4 undefined: 6 *	5	3	2 to OPN
Present series	Fox Chase Cancer Center	100	2.8	206	25.5	127	3.2	II: 5 III: 5 V: 1	5	2	1 to OPN 1 to open radical nephrectomy

NR denotes data not reported

* cardiopulmonary, thromboembolic and bleeding complications that cannot be graded from the reported descriptions

† multi-institutional cohort includes updated data from previously published single institution series.