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ARTICLE

Robotic and open partial nephrectomy for intermediate and high complexity tumors: a matched-pairs comparison of surgical outcomes at a single institution

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ABSTRACT

Objective: To compare peri-operative factors and renal function following open partial nephrectomy (OPN) and robotic partial nephrectomy (RPN) for intermediate and high complexity tumors when controlling for tumor and patient complexity.

Methods: A retrospective review of 222 patients undergoing partial nephrectomy was performed. Patients with intermediate (nephrometry score NS 7–9) or high (NS 10–12) complexity tumors were matched 2:1 for RPN:OPN using NS, Charlson Comorbidity Index (CCI), and BMI. Patient demographics, peri-operative values, renal function, and complication rates were analyzed and compared.

Results: Seventy-four OPN patients were matched to 148 RPN patients with no difference in patient demographics. Estimated blood loss in OPN patients was significantly higher (368.5 vs 210.5 mL, $p < 0.001$) as was transfusion rate (17% vs 1.6%, $p < 0.001$). Warm ischemia time was longer in OPN (25.5 vs 19.7 min, $p = 0.001$) while operative time was reduced (200.5 vs 226.5 min, $p = 0.010$). RPN patients had significantly shorter hospitalizations (5.3 vs 3.0 days, $p < 0.001$). GFR decrease after one month was not statistically significant (12.9 vs 6.6 ml/min, $p = 0.130$). Clavien III–V complications incidence was higher for OPN compared to RPN although not significantly (20.3% vs 10.8%, $p = 0.055$).

Conclusion: When matching for tumor and patient complexity, RPN patients had fewer high grade post-operative complications, decreased blood loss, and shorter hospitalizations. RPN is a safe option for patients with intermediate and high complexity tumors.

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Introduction

There is an increasing body of evidence that shows partial nephrectomy (PN) to be associated with equivalent cancer specific survival and better renal function in patients with localized renal masses compared to radical nephrectomy (RN). PN has become the standard of care for treatment of small renal masses, with newer evidence suggesting a benefit for larger localized masses as well [1–6]. The benefits on kidney function, complication rates, oncologic survival, and comorbidity related mortality in PN are well documented [7–10].

The methods of performing nephron sparing surgery (NSS) have been previously compared and demonstrate similar complication rates and oncologic outcomes between both laparoscopic (LPN) and open (OPN) partial nephrectomy [11,12]. Robotic-assisted partial nephrectomy (RPN) has also been shown to have equal peri-operative outcomes and improved warm ischemia time (WIT) compared to LPN [13]. Currently, there still exists a need to compare RPN and OPN for higher complexity masses in patients with multiple comorbidities. Risk factors for renal cell carcinoma, as well as both morbidity and long-term survival following PN, are impacted by factors such as history of smoking, obesity, diabetes mellitus, and hypertension [14–16]. To properly identify high complexity masses amenable to surgery, uniform classification systems for renal tumors have been developed. The R.E.N.A.L. nephrometry score (NS) classification has demonstrated predictive value in terms of patient outcomes following PN, and higher complexity masses have been demonstrated to be able to be managed by RPN [17–19].

The purpose of this study is to compare OPN with RPN approaches to intermediate and high complexity renal masses in order to examine the efficacy of RPN for these difficult cases.

Methods

Study cohort

Institutional review board exempt status was granted for the conduct of this study. A retrospective review was performed using a prospectively collected database of patients who underwent partial nephrectomy for renal masses amenable to PN at a single institution. Partial nephrectomy was performed by one of eleven senior faculty urologists at the

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institution. Seven faculty urologists performed both open and robotic partial nephrectomies. All adult patients with tumors categorized as intermediate (7–9) or high (10–12) complexity by R.E.N.A.L. nephrometry score (NS) were included. Patients with intermediate and high complexity tumors were matched in a 2:1 ratio of RPN:OPN to minimize confounding variables during comparison. Matching criteria were NS, Charlson Comorbidity Index (CCI), and BMI. CCI was stratified into 0–3 vs 4+ and BMI categories were <25, 25–30, 30–35, and >35. Two hundred and four patients from November 2008 through July 2016 were perfectly matched using these methods and an additional 18 patients were matched perfectly by nephrometry score utilizing closest CCI score and BMI. About half (50.7%) of OPN patients were prior to 2013 whereas just over a quarter (25.6%) of RPN patients were prior to 2013. Prior to 2013, exactly half of patients in the cohort had OPN whereas the other half underwent RPN.

Outcomes

The primary outcome was operative morbidity as evaluated through incidence of Clavien-Dindo classification grade 3–5 complications and transfusion rate [20]. The secondary outcome was post-operative renal function (creatinine and eGFR).

Pre-operative variables examined were age, sex, race, BMI, presence of hypertension, diabetes mellitus, coronary artery disease, history of cerebrovascular accident, current smoking status, Charlson Comorbidity Index, and pre-operative renal function (creatinine and eGFR). Tumor characteristics were analyzed using sidedness, presence of a solitary kidney, tumor diameter, and Nephrometry Score (NS).

Peri-operative values analyzed were estimated blood loss (EBL), warm ischemia time (WIT), operative time, length of post-operative hospital stay. Surgical approaches compared were rates of hilar clamping of renal artery and vein, mass enucleation, entrance to the collecting system, renorrhaphy, and placement of an abdominal drain.

The rate of RCC diagnoses on pathology was also compared post-operatively.

Statistical analysis

Statistical analysis was performed using descriptive statistics to compare OPN and RPN approaches. Continuous variables were analyzed using Student's *t*-test for differences in means of normally distributed variables and the Mann–Whitney *U* test for non-normally distributed data (ex. tumor diameter). Pearson's χ^2 and Fisher's exact tests were used for categorical variables. Statistical tests were all performed two-sided with a significance set as $p < 0.05$.

Results

222 patients were matched with 74 (33%) undergoing OPN and 148 (67%) RPN. Patient demographics are presented in Table 1. There was no difference in age, gender, BMI, comorbidities, or smoking status. The mean nephrometry score for OPN was 8.3 compared to 8.0 in RPN patients ($p = 0.098$). Preoperative GFR was similar between the cohorts, with an average (SD) of 83.3 (28.2) in the OPN group and 76.4 (25.2) in the RPN group ($p = 0.113$). There was no statistically significant difference in average tumor diameter (4.69 in OPN vs 4.06 in RPN, $p = 0.0602$).

Table 2 displays the comparative results of intraoperative outcomes of both surgical approach groups. Both mean and median estimated blood loss and transfusion rates were higher in the OPN cohort. EBL ranged from 50 to 1200 mL in the OPN cohort and from 50 to 1500 in the RPN cohort. However as seen in Table 2, the interquartile range of blood loss for OPN patients was 150–500 versus 100–225 in the RPN group. Furthermore 14/74 (18.9%) OPN patients had an EBL exceeding 500 mL vs only 7/148 (4.7%) RPN patients. This suggests that more OPN cases had higher amounts of blood loss requiring transfusion which would help explain the difference in transfusion rates (17% in OPN vs 1.6% in RPN, $p < 0.001$). Warm ischemia time was significantly higher in the open cohort (25.5 min vs 19.7 min, $p = 0.001$). Operative time was significantly reduced in the open cohort as well (200.5 min vs 226.5 min, $p = 0.010$). When comparing operative techniques, significant differences were seen in rates of renorrhaphy (58.1% in OPN vs 75.7% in RPN, $p = 0.017$). This contrasts with rates of entrance into the collecting system, enucleation, and use of an abdominal drain which did not show significant differences (Table 2).

Post-operative outcomes are displayed in Table 3. Overall, Clavien III–V complications occurred in 20.3% of OPN compared with 10.8% of RPN ($p = 0.055$). One month post-operative GFR values were similar between groups and there was no significant difference seen in GFR decrease at the one month mark. Pathological rates were nearly identical for renal cell carcinoma diagnosis. Other diagnoses classified as 'Other' in Table 3 include xanthogranulomatous pyelonephritis and cystic nephroma.

Discussion

In a matched cohort of patients undergoing partial nephrectomy for intermediate and high complexity renal tumors, RPN was determined to be viable alternative to OPN with no significant effects on renal function. This reinforces the findings of previous studies which have underscored the efficacy of PN for complex renal tumors [1–6]. Previously, laparoscopic PN (LPN) has been shown to have similar complication rates to OPN [11,12]. The results reported in this current study also show that a minimally invasive surgical approach is not associated with higher rates of post-operative complications [11]. In fact, the complication rate in RPN patients (10.8%) was nearly 50% less than their matched OPN counterparts (20.3%). Zhang and colleagues' meta-analysis comparison of LPN to RPN reinforced the use of RPN [13]. The results of this study have provided further evidence supporting the use of RPN for complex renal masses. Zhang et al. reported that amongst length of hospitalization, EBL, WIT, and operative time, only WIT was significantly reduced ($p = 0.01$) in the robotic approach compared to the

Table 1. Demographics of patients undergoing open and robot-assisted partial nephrectomy.

	Open partial nephrectomy	Robot-assisted partial nephrectomy	*p* Value
N	74	148	
Age, mean (SD) [years]	58.2 (12.7)	60.3 (13.1)	0.242
Male, no. (%)	42 (56.8)	87 (58.8)	0.773
African American, no. (%)	8 (10.8)	8 (5.4)	0.118
HTN, no. (%)	48 (64.9)	107 (72.3)	0.255
DM, no. (%)	23 (31.1)	49 (33.1)	0.761
CAD, no. (%)	11 (14.9)	25 (16.9)	0.699
CVA, no. (%)	3 (4.1)	9 (6.1)	0.389
Current smoker, no. (%)	16 (21.6)	33 (22.3)	0.909
Right side, no. (%)	44 (59.5)	82 (55.4)	0.565
Solitary kidney, no. (%)	3 (4.1)	4 (2.7)	0.429
BMI, mean (SD) [kg/m^2]	31.3 (8.4)	31.2 (6.9)	0.878
<25	17 (23.0)	27 (18.2)	0.755
25–30	20 (27.0)	49 (33.1)	
30–35	15 (20.3)	28 (18.9)	
>35	22 (29.7)	44 (29.7)	
Charlson comorbidity index, mean (SD)	3.0 (1.3)	3.3 (2.0)	0.393
0–3	47 (63.5)	94 (63.5)	1.00
4+	27 (36.5)	54 (36.5)	
Tumor diameter, mean (SD) [cm]	4.69 (2.46)	4.06 (1.85)	0.0602
Nephrometry score, mean (SD)	8.3 (1.0)	8.0 (1.1)	0.0979
Intermediate complexity (NS 7–9), no. (%)	65 (87.8)	130 (87.8)	1.00
High complexity (NS 10–12), no. (%)	9 (12.2)	18 (12.2)	
Preoperative creatinine, mean (SD) [mg/dl]	0.99 (0.3)	1.1 (0.4)	0.144
Preoperative GFR, mean (SD) [ml/min]	83.3 (28.2)	76.4 (25.2)	0.113

Table 2. Perioperative values of OPN and RPN patients.

N	Open partial nephrectomy 74	Robot-assisted partial nephrectomy 148	*p* Value
Estimated blood loss, mean (SD) [mL]	368.5 (308.7)	210.5 (208.9)	<0.001
Estimated blood loss, median (IQR) [mL]	200 (150–500)	150 (100–225)	<0.001
Transfusion needed, no. (%)	10 (17.0)	2 (1.6)	<0.001
Warm ischemia time, mean (SD) [min]	25.5 (16.8)	19.7 (8.2)	0.001
Operative time, mean (SD) [min]	200.5 (74.8)	226.5 (65.4)	0.010
Length of stay, mean (SD) [days]	5.3 (4.2)	3.0 (1.6)	<0.001
Hilar clamping of artery and vein, no. (%)	52 (89.7)	99 (83.2)	0.611
Enucleation, no. (%)	59 (79.7)	104 (70.3)	0.989
Entrance to collecting system, no. (%)	36 (69.2)	87 (78.4)	0.206
Renorrhaphy, no. (%)	43 (58.1)	112 (75.7)	0.017
Abdominal Drain, no. (%)	50 (90.9)	98 (89.1)	0.717

Table 3. Outcomes of OPN and RPN patients.

N	Open partial nephrectomy 74	Robot-assisted partial nephrectomy 148	*p* Value
Complications (Clavien III–V), no. (%)	15 (20.3)	16 (10.8)	0.055
1-Month creatinine, mean (SD) [mg/dl]	1.3 (0.8)	1.2 (0.4)	0.295
1-Month eGFR, mean (SD) [ml/min]	71.0 (30.6)	68.6 (25.5)	0.599
1-Month creatinine increase, mean (SD) [mg/dl]	0.28 (0.7)	0.10 (0.2)	0.019
1-Month eGFR decrease, mean (SD) [ml/min]	12.9 (18.2)	6.6 (14.9)	0.130
Pathologic diagnosis, no. (%)			0.582
RCC	63 (85.1)	130 (87.8)	
Oncocytoma	4 (5.4)	9 (6.1)	
Angiomyolipoma	2 (2.7)	1 (0.7)	
Benign cyst	1 (1.4)	3 (2.0)	
Benign cortical cyst	0 (0)	2 (1.4)	
Chronic Inflammation	2 (2.7)	1 (0.7)	
Other	2 (2.7)	2 (1.4)	
RCC subtype, no. (%)			0.491
Clear	48 (76.2)	99 (76.2)	
Papillary	7 (11.1)	14 (10.8)	
Chromophobe	2 (3.2)	8 (6.2)	
Unclassified	5 (7.9)	3 (2.3)	
Translocation	0 (0)	1 (0.8)	
Other	1 (1.6)	5 (3.8)	
Pathologic staging, no. (%)			0.170
pT1a	44 (69.9)	97 (74.6)	
pT1b	12 (19.0)	26 (20)	
pT2a	2 (3.2)	0 (0)	
pT2b	1 (1.7)	0 (0)	
pT3a	4 (6.3)	7 (5.4)	

laparoscopic approach for partial nephrectomy, and no difference in complication rates were seen in the six studies analyzed in their study ($p = 0.27$). In contrast, the present study showed a reduction in WIT, blood loss and hospitalization lengths for RPN compared to OPN patients while operative time was increased. No significant difference in complication rates was noted.

A number of recent studies have compared RPN to OPN for higher complexity renal masses. Garisto et al. [21] performed a retrospective review of high complexity tumors, defined as NS $>$ 9, managed by RPN and OPN and reported significant reductions in blood loss, transfusion rates, warm ischemia time, and hospitalization length for the robotic cohort. The present cohort was analyzed in a 2:1 RPN:OPN matched pair method in order to control for both tumor and patient complexity and provide increased evidence in support of RPN. However the present study controlled for both tumor and patient complexity with matched pairing of OPN and RPN patients. The benefit of matching minimizes confounding variables and adds to the current body of evidence supporting RPN as an efficacious approach to complex renal masses. Statistically significantly reductions in blood loss, transfusion rate, warm ischemia time, and hospitalization lengths when comparing RPN to OPN in a matched comparison are more attributable to surgical approach. Similarly the greater increase in serum creatinine levels postoperatively in OPN patients in this study can more directly be associated with partial nephrectomy approach especially given that no difference was observed in preoperative serum creatinine between groups. Decrease in eGFR also was greater in OPN patients although not quite statistically significant. Additionally, while Garisto et al. analyzed solely patients with NS $>$ 9, in the current study, intermediate complexity tumors were additionally included. Wang et al. [22] similarly performed a matched comparison of RPN and OPN for patients with NS $>$ 7 and reported that RPN provided the benefits of shorter LOS, decreased EBL and lower complication.

The results of this study must be viewed in the context of certain limitations. As a retrospective study, patient demographics and comorbidities are not all controlled; however, matching was performed to mitigate this limitation. Additionally, there may be factors that caused surgeons to choose OPN that were not reflected in the Nephrometry Score and it is important to acknowledge that selection of patients may have been different throughout the course of this study. The study is additionally subject to selection bias as it was conducted at a tertiary referral center that is high volume in the management of renal masses. The partial nephrectomies were performed by multiple surgeons at this single institution so surgical technique and post-operative monitoring were not standardized. Our surgeons are all sub specialized with only 3 surgeons whose area of interest is robotic partial nephrectomies. Other surgeons perform the surgery occasionally. However, we have included all patients to represent a real life scenario in a tertiary care referral center like ours. While we observed a statistically significant difference in EBL between surgical approaches it is important to acknowledge that this difference is likely not clinically significant. Additionally, while the 30-day complication rate is helpful, it does not allow examination or comparison of complications that occurred beyond the initial post-operative period. As 50% of our OPN were performed in 2013 or earlier, both clamping and surgical technique are likely varied from current established approach. Finally, we did not study whether the discovery of renal masses were symptomatic or incidental. These limitations notwithstanding, the presented study offers a matched cohort that examines early perioperative and post-operative outcomes comparing robotic and open partial nephrectomy.

Conclusion

In a matched cohort of patients undergoing partial nephrectomy, intermediate and high complexity tumors managed with RPN (compared with OPN) have equivalent changes in renal function after surgery and better post-operative outcomes. This matched cohort is one of the largest single institution comparisons between RPN and OPN and suggests that patients amenable to robotic-assisted approaches with well-trained surgeons may have improved post-operative outcomes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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