Comparison of Robot-Assisted and Laparoscopic Partial Nephrectomy for Renal Hilar Tumors: Results from a Tertiary Referral Center

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Abstract

Objective: To compare perioperative, functional, and oncologic outcomes between robot-assisted partial nephrectomy (RAPN) and laparoscopic partial nephrectomy (LPN) for renal hilar tumors.

Methods: We retrospectively reviewed patients who underwent minimally invasive partial nephrectomy for renal hilar tumors at our institution between January 2014 and August 2018. The entire cohort was divided into two groups according to surgical approach: RAPN and LPN group. Perioperative, functional, and oncologic outcomes of the two groups were collected and compared.

Results: A total of 116 patients with renal hilar tumors were identified, including 52 patients who underwent RAPN and 64 patients who underwent LPN, respectively. Demographic baseline characteristics were similar in two groups. There were no differences between the RAPN and LPN groups for operative time, transfusion rate, conversion rate, surgical margin, perioperative complication, and hospital stay. Compared with the LPN group, the RAPN group was associated with significant less estimated blood loss (100 vs 150 mL; $p < 0.001$), shorter warm ischemia time (20.3 vs 24.5 minutes; $p = 0.001$), and higher direct cost ($p < 0.001$). Percentage of estimated glomerular filtration rate change at 6 months after surgery was lower in RAPN group than LPN group (10.4% vs 15.2%; $p = 0.020$). No significant difference was observed between the two groups in terms of oncologic outcomes.

Conclusions: For hilar tumors, both RAPN and LPN were safe and feasible surgical treatments. RAPN might be associated with superior perioperative outcomes (less estimated blood loss and shorter warm ischemia time) and better postoperative renal functional preservation. RAPN might be the preferred option when condition permits for renal hilar tumors.

Keywords: renal hilar tumor, partial nephrectomy, robotics, laparoscopy

Introduction

CURRENTLY, PARTIAL NEPHRECTOMY (PN) is recommended for the surgical treatment of clinical T_{1a} renal masses, because accumulating evidence has suggested that PN could preserve renal function and achieve equivalent oncologic outcomes compared with radical nephrectomy (RN). Due to its advantages, PN is also considered an option for selected T_{1b} and T_{2a} cases when technically feasible.¹ Compared with open PN, minimally invasive PN offers multiple advantages to patients, including less intraoperative estimated blood loss, improved postoperative pain, and decreased length of hospital stay, which has been proven by a large number of series.^{2,3}

Renal hilar tumor, as a particular type of renal masses, has traditionally been performed PN via an open surgery. In 2005, Gill and colleagues⁴ first reported that laparoscopic partial nephrectomy (LPN) in the treatment of renal hilar tumors was feasible. However, this technique requires significant expertise due to its anatomic location. Since the introduction of the robot-assisted surgery system, robot-assisted partial nephrectomy (RAPN) has been considered an evolution of LPN, which offers several peculiar advantages, including seven degrees of motion, three-dimensional visualization, elimination of surgeons' tremors, and enhanced dexterity. The widespread adoption of robot-assisted system further broadens the indication of PN for some complex cases including hilar tumors.^{5–9} Up to now, several studies have

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shown that RAPN is more favorable than LPN for challenging cases.^{10–12} However, to the best of our knowledge, there is no study that directly compares the clinical outcomes of RAPN and LPN for renal hilar tumors.

In the present study, we retrospectively reviewed patients with renal hilar tumors who were treated with RAPN or LPN between January 2014 and August 2018 at our institution, and conducted a study comparing the perioperative, functional, and oncologic outcomes of these two surgical approaches.

Methods

Study population

The data were extracted from a maintained renal tumor database approved by our institutional review board. Patients with a solitary kidney, multifocal or bilateral tumors, recurrent or metastatic disease were excluded, and a total of 116 consecutive patients who underwent RAPN or LPN for hilar tumors were identified between January 2014 and August 2018 at the First Affiliated Hospital of Nanchang University. All patients underwent preoperative imaging examination with contrast-enhanced CT or MRI. A hilar tumor was defined as a tumor located in the renal hilum region abutting the renal artery and/or vein on preoperative imaging, in accordance with previous studies.^{4,6,13,14} Every imaging was reviewed by two independent senior surgeons.

According to the surgical procedure type, the patients were stratified into two groups: RAPN and LPN. The RAPN and LPN surgical procedures were all performed by experienced and high-volume surgeons using either a transperitoneal or retroperitoneal approach. Detailed operative procedures of RAPN and LPN have been described in previous published literature.^{15–17} This research was approved by our institution's ethics committee, and written informed consent was acquired from all included patients.

Data collection

Baseline demographics and perioperative clinical data were obtained from our institution's renal tumor database. Tumor complexity was evaluated by the RENAL (Radius, Exophytic/Endophytic, Nearness, Anterior/Posterior, Location) nephrometry scoring system on preoperative imaging,¹⁸ and was stratified as low, moderate, or high, if the RENAL score was 4 to 6, 7 to 9, and 10 to 12, respectively. Intraoperative and postoperative complications were recorded by using the modified Clavien–Dindo classification system. Minor complications were defined as grades 1 to 2 and major complications were defined as grades 3 to 5, respectively. All specimens were reviewed by two independent urologic pathologists in our center. Pathologic Tumor Node Metastasis (TNM) staging was performed according to the 8th American Joint Committee on Cancer staging system, and histologic subtypes were identified according to the 2016 version of the World Health Organization classification. A positive surgical margin was defined as the presence of cancerous cells at the level of the inked surface of the resected specimen.

Renal function was assessed by estimated glomerular filtration rate (eGFR), and the Modification of Diet in Renal

Disease (MDRD) formula was applied to calculate eGFR. Preoperative eGFR, postoperative eGFR (24 hours and 6 months), and their changes were calculated and recorded. Postsurgical follow-ups were conducted in all patients. Physical examination, laboratory tests, and ultrasound or CT scan were performed every 3 or 6 months for the first 2 years, and were conducted annually after the second year. Disease and vital statuses were updated through regular clinic follow-up or telephone interview.

Statistical analysis

All continuous variables were presented as mean and standard deviation or median and interquartile range, as appropriate. For continuous variables, independent *t*-test or Mann–Whitney U test was applied to analyze the comparisons. For categorical variables, Pearson chi-square or Fisher's exact test was selected to analyze the comparisons. A multiple linear regression was conducted to analyze potential predictors of postoperative eGFR decline 6 months after surgery. Recurrence-free survival (RFS) rates for the RAPN group and LPN group were performed using the Kaplan–Meier method with log-rank test. All analyses were conducted using SPSS 23.0 (SPSS, Inc., Chicago, IL). All comparisons were two-sided and a $p < 0.05$ was considered statistically significant.

Results

Patients' baseline characteristics

A total of 52 patients who underwent RAPN and 64 patients who underwent LPN were identified, respectively. The clinical and pathologic characteristics of patients are shown in Table 1. No significant differences for sex, age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, Charlson comorbidity index (CCI) score, presence of hypertension, diabetes, smoking, proteinuria, and tumor laterality were found between the two groups. In addition, mean tumor size (4.3 vs 4.1 cm; $p = 0.469$) and tumor complexity ($p = 0.696$) of the two groups were similar, and patients in the RAPN group had a comparable preoperative creatinine (76.4 vs 79.2 $\mu\text{mol/L}$; $p = 0.493$) and preoperative eGFR (87.5 vs 84.8 mL/minute/1.73 m²; $p = 0.544$) with the LPN group.

Perioperative outcomes of RAPN vs LPN

Table 2 summarizes perioperative outcomes of the RAPN and LPN groups. Mean operative time was similar in two groups (130.3 vs 126.6 minutes; $p = 0.636$). However, the RAPN group was correlated with less intraoperative median estimated blood loss (100 vs 150 mL; $p < 0.001$). Besides, the warm ischemia time for patients in the RAPN group was significant shorter than that for patients in the LPN group (20.3 vs 24.5 minutes; $p = 0.001$). The rates of transfusion, intraoperative, and postoperative complications were comparable between the two groups. One patient in RAPN group had conversion to RN because of insufficient residual kidney, and three patients in LPN group had conversion to RN because of insufficient residual kidney or intraoperative hemorrhage. In addition, one case in LPN group had conversion to open surgery for inferior vena cava injury. There was no significant difference

TABLE 1. BASELINE DEMOGRAPHIC AND TUMOR CHARACTERISTICS OF RENAL HILAR TUMORS

Variable	RAPN (N=52)	LPN (N=64)	p
Sex, male, <i>n</i> (%)	33 (63.5)	40 (62.5)	0.915
Age, years, mean $\pm$ SD	54.7 $\pm$ 12.1	52.8 $\pm$ 11.5	0.389
BMI, kg/m ² , mean $\pm$ SD	25.2 $\pm$ 4.4	24.6 $\pm$ 3.8	0.432
ASA score, mean $\pm$ SD	1.9 $\pm$ 0.4	2.0 $\pm$ 0.3	0.127
CCI score, <i>n</i> (%)			0.841
0 to 1	44 (84.6)	55 (85.9)	
≥ 2	8 (15.4)	9 (14.1)	
Presence of hypertension	17 (32.7)	25 (39.1)	0.478
Presence of diabetes	7 (13.5)	10 (15.6)	0.743
Presence of smoking	15 (28.8)	24 (37.5)	0.326
Presence of proteinuria	2 (3.8)	3 (4.7)	0.824
Laterality, left, <i>n</i> (%)	28 (53.8)	30 (46.9)	0.455
Tumor size, mean $\pm$ SD	4.3 $\pm$ 1.3	4.1 $\pm$ 1.6	0.469
RENAL score, <i>n</i> (%)			0.696
Intermediate	29 (55.8)	38 (59.4)	
High	23 (44.2)	26 (40.6)	
Preoperative creatinine, μ mol/L, mean $\pm$ SD	76.4 $\pm$ 24.6	79.2 $\pm$ 19.2	0.493
Preoperative eGFR, mL/minute/1.73 m ² , mean $\pm$ SD	87.5 $\pm$ 22.2	84.8 $\pm$ 25.0	0.544

ASA = American Society of Anesthesiologists; BMI = body mass index; CCI = Charlson comorbidity index; eGFR = estimated glomerular filtration rate; LPN = laparoscopic partial nephrectomy; RAPN = robot-assisted partial nephrectomy; RENAL = Radius, Exophytic/Endophytic, Nearness, Anterior/Posterior, Location; SD = standard deviation.

in postoperative hospital stay between the two groups, however, RAPN was associated with a higher hospital cost (5.5 vs 3.8 ten thousand Yuan, $p < 0.001$).

Postoperative functional and oncologic outcomes of RAPN vs LPN

Renal functional outcomes of both groups are listed in Table 3. After surgery, the eGFR had declined in both groups. The percentage of eGFR decline was slightly higher in the LPN group than RAPN group on the first postoperative day (16.5% vs 12.6%), but the difference did not reach statistical significance ($p = 0.066$). However, there existed significant difference in the percentage eGFR decline between both

groups at 6 months after surgery (15.2% vs 10.4%; $p = 0.020$). Moreover, multivariable linear analysis indicated that the surgical approach could well predict postoperative eGFR decline ($p = 0.002$) (Supplementary Table S1).

The postoperative pathologic examination revealed that most cases had malignant tumor and belonged to T₁ stage tumor. There was no positive surgical margin in either group. The median follow-up for RAPN and LPN was 21.8 and 25.2 months, respectively. During follow-up, there was no cancer-related death. Two local recurrence events occurred in the LPN group at 15 and 36 months after surgery, respectively, and one local recurrence event was noted in the RAPN group at 24 months after surgery. There was no significant difference regarding 3-year RFS rates between the two groups ($p = 0.441$).

TABLE 2. PERIOPERATIVE CHARACTERISTICS OF THE STUDY POPULATION

Variable	RAPN (N=52)	LPN (N=64)	p
Operating time, minutes, mean $\pm$ SD	130.3 $\pm$ 35.4	126.6 $\pm$ 46.2	0.636
Estimated blood loss, mL, median (IQR)	100 (50–160)	150 (100–200)	<0.001
Warm ischemia time, minutes, mean $\pm$ SD	20.3 $\pm$ 6.4	24.5 $\pm$ 7.0	0.001
Transfusion, <i>n</i> (%)	2 (3.8)	5 (7.8)	0.457
Conversion to radical, <i>n</i> (%)	1 (1.9)	3 (4.7)	0.399
Conversion to open, <i>n</i> (%)	0	1 (1.6)	1.000
Malignant histology, <i>n</i> (%)	45 (86.5)	54 (84.4)	0.743
T stage, <i>n</i> (%)			0.245
T ₁	37 (71.2)	49 (76.6)	
T ₂	7 (13.5)	3 (4.7)	
T _{3a}	1 (1.9)	2 (3.1)	
Positive surgical margin, <i>n</i> (%)	0	0	1.000
Intraoperative complications, <i>n</i> (%)	2 (3.8)	4 (6.3)	0.561
Postoperative complications, <i>n</i> (%)	9 (17.3)	15 (23.4)	0.418
Minor, Clavien 1 to 2	8 (15.4)	13 (20.3)	0.493
Major, Clavien 3 to 4	1 (1.9)	2 (3.1)	0.685
Postoperative hospital stay, days, mean $\pm$ SD	5.2 $\pm$ 1.2	5.4 $\pm$ 1.0	0.330
Hospital cost, 10,000 Yuan, mean $\pm$ SD	5.5 $\pm$ 0.5	3.8 $\pm$ 0.7	<0.001

IQR = interquartile range.

TABLE 3. RENAL FUNCTIONAL OUTCOMES FOR ROBOT-ASSISTED PARTIAL NEPHRECTOMY AND LAPAROSCOPIC PARTIAL NEPHRECTOMY

Time point	Variable	RAPN	LPN	p
Preoperative	eGFR, mL/minute/1.73 m ² , mean ± SD	87.5 ± 22.2	84.8 ± 25.0	0.544
24 Hours after surgery	eGFR, mL/minute/1.73 m ² , mean ± SD	76.6 ± 21.4	70.6 ± 24.6	0.169
	eGFR decline in baseline, mL/minute/1.73 m ² , mean ± SD	10.9 ± 10.3	14.2 ± 11.4	0.108
	eGFR decline, %, mean ± SD	12.6 ± 9.2	16.5 ± 12.7	0.066
6 Months after surgery	eGFR, mL/minute/1.73 m ² , mean ± SD	78.3 ± 21.2	71.8 ± 23.8	0.127
	eGFR decline in baseline, mL/minute/1.73 m ² , mean ± SD	9.2 ± 8.6	13.0 ± 10.2	0.035
	eGFR decline, %, mean ± SD	10.4 ± 9.7	15.2 ± 11.8	0.020

Discussion

The incidental detection of renal masses is increasing in recent decades because of the widespread use of noninvasive radiologic imaging tools. With the improvements in minimally invasive surgical techniques, application of robotic or laparoscopic nephron-sparing surgical procedure in small localized renal tumor is gaining popularity in recent years. PN for renal hilar tumors has traditionally been performed by open surgery. A series of recent studies have suggested that hilar tumors removed by robotic or laparoscopic PN had good feasibility and safety.^{4,13,19,20} Miyake and colleagues²¹ reported their outcomes in hilar tumors using open or robotic approaches and found that RAPN was an effective, safe, and less invasive surgical option for renal hilar tumors when compared with open partial nephrectomy. Another similar study by Sagalovich and coworkers²² demonstrated that there was no significant difference between open and RAPN “trifecta” rate (negative margins, zero complications, and glomerular filtration rate preservation of ≥90%), and RAPN provided quicker recovery and decreased length of hospital stay. However, in the era of minimally invasive surgery, limited information has been available from direct comparison of clinical outcomes between RAPN and LPN for renal hilar tumors, and this interesting clinical issue needs to be discussed and validated.

In the present study, we analyzed the data of 116 renal hilar tumors that underwent minimally invasive nephron-sparing surgery in our center. According to our institution’s experience, RAPN had its significant perioperative advantages, namely lower estimated blood loss and shorter warm ischemia time when compared with LPN. These results were in accordance with several previous studies comparing RAPN and LPN.^{10,23} The three-dimensional visualization, improved degrees of freedom, and agile wrists of the manipulator system especially well suited to facilitate tumor resection as well as renorrhaphy of a robotic surgical system might account for its perioperative advantages. However, the postoperative hospital stay was similar in the two groups for these challenging cases. Postoperative hospital stay in our center was slightly longer than the lengths in other tertiary centers of Western countries,²⁴ which might be partly attributed to the evident differences in the medical insurance systems of different countries and regions. In terms of safety, the postoperative complication rates for RAPN and LPN were 17.3% and 23.4% (nonsignificant difference), respectively, which were similar with other reported RAPN and LPN series.^{11,24} More importantly, the majority of these complications were minor and classified as Clavien grades 1 to 2, which further suggested that both RAPN and LPN were safe and feasible for the management of hilar tumors.

Oncologic outcomes are of great important concern in the surgical approach to renal tumors. Numerous studies have proved that minimally invasive PN presents oncologic outcomes comparable with open surgery.^{25,26} In terms of hilar tumors, a previous study by Miyake and colleagues²¹ demonstrated that there was no difference between robotic and open surgery in positive margin rate, in accordance with another research reported by Sagalovich and coworkers.²² In our study, most tumors were malignant and no positive surgical margin existed in either group. There was no cancer-related death in the patients, and the difference in RFS rates between the two groups was nonsignificant. Thus, equivalent oncologic outcomes could be achieved in hilar tumors performed by RAPN or LPN.

The preservation of renal function is another important issue to be concerned in PN. For hilar tumors, according to our data, patients in the RAPN group presented a significantly smaller decline in postoperative eGFR than those in the LPN group. Consistent with our results, Gu and colleagues²⁷ and Wu and colleagues²³ found that RAPN was associated with a significantly better preservation of postoperative function. This advantage in preservation of function might be partly attributed to the shorter renal artery clamp time of RAPN group. In addition, compared with laparoscopic surgery, robotic surgery might reduce the amount of normal parenchymal loss leading to superior preservation of nephrons and renal function. Besides, better visualization and more precise control of robotic surgical system could facilitate functional volume preservation, which was reported to be the major determinant of long-term kidney function in patients whose ischemia time was within acceptable limits,²⁸ and avoid vessel injury during resection and suturing, especially in hilar tumors that were in close proximity to the major renal vessels.

The widespread adoption of the robot system has taken a revolution in surgery and attracted extensive attention over the recent years. In our institution, after introduction of a robotic system, RAPN has become the preferred nephron-sparing surgical approach for technically challenging renal tumors. Based on our experience, for renal hilar tumors, RAPN appears to be more favorable in terms of superior perioperative outcomes and better postoperative renal functional preservation than LPN. However, the expense should also be considered in clinical practice; according to our data, the direct expense of robotic surgery is significantly higher than laparoscopic surgery. The treatment decision to select robotic surgery or conventional laparoscopic surgery remains complicated and must balance the cost/benefit of an individual approach in clinical practice. The results of our present

study could be used in counseling patients with hilar tumors and provide important information for clinical decision-making about surgical strategies.

Several limitations also exist in the present study. The retrospective design of our work and its restriction to a single institution with relatively small cases were the main drawbacks of our study. Besides, the allocation of both approaches was nonrandomly selected in clinical practice, which might produce bias. Although several important factors (e.g., BMI, tumor size, RENAL score, and preoperative eGFR) were comparable in the two groups, it is possible that potential selection bias or some unmeasured confounders existed. Moreover, MDRD is known to be effective in patients with eGFR <60 mL/minute/1.73 m², while the mean preoperative and postoperative eGFR was >70 mL/minute/1.73 m² in the two groups, which was another limitation in our study. Besides, given the relatively short follow-up, it is difficult to draw a conclusion with regard to long-term oncologic outcomes between the robotic and laparoscopic cohorts. In addition, some innovative surgical techniques such as selective arterial clamping and early unclamping were applied to some of the cases receiving RAPN, which might have an impact on the postoperative renal functional outcomes.²⁹ We postulated that robotic surgery might reduce the amount of normal parenchymal loss, however, a lack of accurate volumetric measurement was another limitation in this study, which needed to be explored in future studies. Despite the above limitations, our study remains the first study to date in which the perioperative outcomes (surgical, oncologic, and functional) of RAPN and LPN for renal hilar tumors are directly evaluated.

Conclusions

In summary, both RAPN and LPN were safe and feasible options for the treatment of renal hilar tumors. Compared with LPN, RAPN might be associated with superior perioperative outcomes (less estimated blood loss and shorter warm ischemia time) and better postoperative renal functional preservation, but with more direct-cost. RAPN might be the preferred option when condition permits for renal hilar tumors. Future randomized trials involving multiple centers with larger data sets and long-term follow-up are needed to further confirm our study's results.

Author Disclosure Statement

No competing financial interests exist.

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Supplementary Material

Supplementary Table S1

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Abbreviations Used

ASA = American Society of Anesthesiologists
 BMI = body mass index
 CCI = Charlson comorbidity index
 CT = computed tomography
 eGFR = estimated glomerular filtration rate
 IQR = interquartile range
 LPN = laparoscopic partial nephrectomy
 MDRD = Modification of Diet in Renal Disease
 MRI = magnetic resonance imaging
 PN = partial nephrectomy
 RAPN = robot-assisted partial nephrectomy
 RENAL = Radius, Exophytic/Endophytic, Nearness, Anterior/Posterior, Location
 RFS = recurrence-free survival
 RN = radical nephrectomy
 SD = standard deviation
 TNM = Tumor Node Metastasis