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ORIGINAL ARTICLE

Evaluation of the Clinical Use of Robot-Assisted Retroperitoneal Laparoscopy and Preoperative RENAL Scoring for Nephron Sparing Surgery in Renal Tumor Patients

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Abstract The present study aims to compare the operative outcomes following the use of robot-assisted retroperitoneal partial nephrectomy (RARPN) with radius, exophytic/endophytic, nearness to sinus, anterior/posterior, and location (RENAL) scoring or laparoscopic retroperitoneal partial nephrectomy (LRPN) for the treatment of renal tumors. Eighty-three nephron-sparing surgery (NSS) procedures performed between January 2013 and December 2015 were reviewed. The study set consisted of 26 robot-assisted retroperitoneal laparoscopes, of which 3 were high risk (RENAL score ≥10), 11 were medium risk (RENAL score ≥7 < 9), and 12 were low risk (RENAL score <7) and 57 laparoscopic retroperitoneal partial nephrectomy procedures (7 high, 22 medium, and 28 low risk). All surgeries were successful in the absence of conversion or transfusion. Operative times were 96.0 ± 16.9 and 110.0 ± 19.4 min for RARPN and LRPN, respectively ($P < 0.05$). Warm ischemia times (WITs) were 17.6 ± 3.1 and 22.8 ± 3.5 min, respectively ($P < 0.05$). Estimated blood losses (EBLs) were 45 ± 15 and 97 ± 25 mL, respectively ($P < 0.05$). No statistical significance was found in duration of drainage, intestinal recovery time, hospital stay, serum creatinine, and perioperative complications ($P > 0.05$). RARPN affords significant advantages in outcomes of WIT, EBL, and recovery time over conventional LRPN owing to an increased accuracy in excision and suturing. Patients bearing high-risk renal tumors (RENAL score ≥10) are suitable candidates for RARPN.

Keywords Renal tumor · Retroperitoneal laparoscopic partial nephrectomy · Robot-assisted retroperitoneal partial nephrectomy · RENAL score

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Background

The incidence of renal carcinoma has increased by 2 to 4% annually between 1975 and 1995 [1], with localized renal tumors being more frequently detected before clinical presentation due to an increased uptake in health and in the use of cross-sectional abdominal imaging [2]. Accordingly, nephron-sparing surgery (NSS) has emerged as the gold-standard treatment for non-advanced renal tumors. Laparoscopic partial nephrectomy affords an equivalent in disease-specific outcomes, but with shortened convalescence compared with open partial nephrectomy [3]. However, conventional laparoscopic surgery is limited by the instability of the laparoscopic lens, which affords only a two-dimensional visual field, and by the limited access for surgical instruments arising from the keyhole puncture wound. The emergence of robot-assisted retroperitoneal partial nephrectomy (RARPN) significantly reduces the complexity of laparoscopic retroperitoneal partial nephrectomy (LRPN), while increasing the accuracy in the resection. Consequently, RARPN is most suitable for treating moderately or highly complex renal mass according to a ≥7 radius, exophytic/endophytic, nearness to sinus, anterior/posterior, and location (RENAL) nephrometry score [4].

Preoperative surgical planning based on tumor imaging is crucial for directing surgery and improving outcomes. Currently, numerous tumor scoring algorithms, which use CT images to quantitatively assess tumor anatomy, have been devised [4–6]. Of these, the RENAL score developed by Kutikov and Uzzo [4] is the first nephrometry scoring algorithm to be widely implemented in clinical practice. Herein, we present a comparative study of the operative outcomes following RARPN and LRPN performed by a single surgeon at our institution.

Methods

Study Set

The present study was a retrospective cohort study. Eighty-three patients who underwent NSS (26 RARPN and 57 LRPN) for treatment of renal tumor between January 2013 and December 2015 were retrospectively enrolled. Patients were eligible if they (1) had a confirmed renal tumor diagnosis suitable for NSS that had presented symptomatically; (2) under adequate communication between doctors and patients (which includes notifying the details of the illness and the difference of two operative types), the operative mode is adopted by the patient; (3) had no surgery-related contraindications and is suitable for general anesthetic; and (4) had, or their families had, consented to surgery with the possibility of radical nephrectomy or open surgery. Patients who did not meet all of the previous criteria were excluded.

Radius, Exophytic/Endophytic, Nearness to Sinus, Anterior/Posterior, and Location Score

All patients underwent preoperative imaging with color Doppler ultrasound, chest radiograph, and multislice spiral CT angiography (MSCAA) of the renal artery. Tumors were stratified according to their RENAL score into high-risk (RENAL score ≥10), middle-risk (RENAL score ≥7 < 9), or low-risk groups (RENAL score <7) (for detailed RENAL score standardization, refer to [4]).

Robot-Assisted Retroperitoneal Partial Nephrectomy

RARPN was performed using the da Vinci Si® system (Intuitive Surgical, Sunnyvale, USA) consisting of three robotic arms. All patients underwent tracheal intubation and intravenous anesthesia. Ambulatory blood pressure and dynamic CO_2 partial pressure were monitored via arterial intubation.

After anesthesia had been induced, the patient was positioned in the lateral recumbent position, with the target kidney site exposed by elevation of the contralateral lumbar region. A 3-cm incision (point A) was made through the psoas muscle at 2 cm below the twelfth rib in the ipsilateral posterior axillary line. Upon breaching the lumbodorsal fascia, the surgeon's index finger was used to penetrate through the muscle into the retroperitoneal space. Next, the retroperitoneal space was accessed, by pushing away the peritoneum and retroperitoneal fat with an index finger, and expanded upon insertion of a balloon into the retroperitoneal space, which was subsequently expanded by insufflation with ~1000 mL gas for 5 min. Following retroperitoneal expansion, a 12-mm robotic trocar (trocar 1) was inserted 2 cm above the iliac crest and fixed with a 4/0-gauge wire. Next, an 8-mm robotic trocar (trocar 2) was placed at point A and fixed with 4/0-gauge wire. A robot-assisted laparoscope was inserted into the retroperitoneal space through trocar 1, and an 8-mm robotic electric monopole trocar (trocar 3) was inserted along the anterior axillary line at twelfth rib with aid of laparoscopic vision. Finally, a 12-mm assistant trocar (trocar 4) was inserted laterally inferior to trocar 3. Using the extension line of the connection between point A and kidney as a guide, the mechanical arm of robot was pushed to the side of the patient's head until the robotic central pillar, lens arm, and extension line overlapped, thereby positioning the robotic camera lens above point A. The robotic arms were then docked completely. The robotic laparoscopic camera, electric monopole, and bipolar coagulation forceps were installed and inserted into retroperitoneal space through their respective trocar. The retroperitoneal space was insufflated with CO_2 gas to a maximum pressure of 16 mmHg. The surgical instruments were bought into direct vision of the laparoscopic camera, with the lens titled 30° upwards, enabling extraperitoneal fat exposure. Next, the Gerota's fascia was opened longitudinally to expose the kidney and localized tumor. Intraoperative use of a laparoscopic ultrasound probe aided tumor identification and directed the resection lines, if necessary. The renal parenchyma was marked by using electrocautery, maintaining a 0.5-cm tumor margin, and the renal artery was blocked with a non-traumatic vascular clamp following intravenous injection with 2 g inosine. The renal tumor was excised with a 0.5- to 1.0-cm resection margin. The renal parenchyma with capsule was sutured with a 1-0-gauge Vicryl attached to Hem-o-lok chip.

Signs of abnormal bleeding of the wound surface or atypical coloration of the renal surface were monitored after the non-traumatic vascular clamp was released from the renal artery. A retroperitoneal drainage tube was fitted at the end of the operation.

Laparoscopic Retroperitoneal Partial Nephrectomy

The patient was anesthetized and positioned as per the RARPN procedure. Next, a 2-mm laparoscopic trocar (elastic separating plier) was inserted to a depth of 2 cm along the posterior axillary line below the twelfth rib. Next, a 10-mm trocar (laparoscopic camera) was inserted 2 cm above the iliac crest and a 10-mm laparoscopic trocar (ultrasound knife) was inserted along the anterior axillary line below the twelfth rib. Following patient anesthetic and trocar insertion, the LRPN was completed as per the RARPN procedure.

Postoperative Care

All patients (RARPN and LRPN) were bed rested for 1 week after surgery and were administered antibiotics. The retroperitoneal drainage tube was removed when appropriate. Patients' data regarding operation time (OT; excluding robot preparation time in RARPN group), warm ischemia time (WIT), estimated blood loss (EBL), retroperitoneal drainage time, intestinal recovery time, postoperative hospital stay duration, preoperative and postoperative serum creatinine, surgical complication rate, and hospitalization cost were reviewed retrospectively. Patients underwent postoperative monitoring with complete blood count, biochemical tests, color Doppler ultrasound, and CT.

Statistical Analyses

All measurement data are presented as the mean ± standard deviation. Intergroup comparisons (RARPN vs. LRPN) in age, BMI, tumor size, RENAL score, OT, WIT, EBL, retroperitoneal drainage time, intestinal recovery time, postoperative hospital stay duration, preoperative and postoperative serum creatinine, surgical complication rate, and hospitalization cost were compared using the independent sample *t* test. The chi-squared test was used to compare intergroup differences in sex, clinical symptoms, tumor side, and perioperative complications. Differences in preoperative and postoperative serum creatinine levels in the same patient were assessed using the paired-samples *t* test. A P value <0.05 was considered statistically significant. All analyses were performed within SPSS Version 19.0 (SPSS Inc., Chicago, US).

Results

Baseline Characteristics

All tumors were non-advanced (cT1N0M0) as determined by imaging data, with the exception of 4 patients with cT2aN0M0-stage tumors in the LRPN group and 1 patient in the RARPN group who was admitted with a solitary renal tumor with hepatic metastases (cT1N0M1). There were 7 and 12 patients in RARPN and LRPN groups, respectively, who had received previous abdominal operations. The baseline characteristics of the study set are presented in Table 1. There were no significant differences (RARPN vs. LRPN) in the age (54.0 ± 14.8 vs. 50.5 ± 15.1; $P = 0.326$), BMI (23.0 ± 3.2 vs. 22.0 ± 3.1; $P = 0.192$), sex ($P = 0.248$), tumor laterality ($P = 0.344$), clinical symptoms ($P = 0.084$), or tumor size (3.6 ± 1.7 vs. 4.0 ± 1.7 cm; $P = 0.365$) of patients receiving RAR or LRPN.

Table 1 Baseline characteristics of study set

	RARPN	LRPN	*P* value
Patients (*n*)	26	57	
Age (mean ± SD)	54.0 ± 15.0	50.5 ± 15.1	0.326[a]
Sex			
Male (*n*)	16	27	0.248[a]
Female (*n*)	10	30	
BMI (mean ± SD, kg/m^2)	23.0 ± 3.2	22.0 ± 3.1	0.192[a]
Tumor side			
Left (*n*)	11	32	0.344[b]
Right (*n*)	15	25	
Tumor size (mean ± SD, cm)	3.6 ± 1.7	4.0 ± 1.7	0.365[a]
Clinical symptoms			
Positive (*n*)	12	15	0.084[b]
Negative (*n*)	14	42	

RARPN robot-assisted retroperitoneal partial nephrectomy, *LRPN* laparoscopic retroperitoneal partial nephrectomy, *BMI* body mass index

[a] Student's *t* test (unpaired)

[b] Chi-squared test

Radius, Exophytic/Endophytic, Nearness to Sinus, Anterior/Posterior, and Location Score

Of the 26 patients who underwent RARPN, 3 were high risk, 11 were medium risk, and 12 were low risk according to RENAL scoring (average was 6.8, ranging from 4 to 10). Of the 57 patients who underwent LRPN, 7 were high risk, 22 were medium risk, and 28 were high risk (average was 6.8, ranging from 4 to 10). There were no significant differences in the RENAL scores of patients undergoing RARPN or LRPN ($P < 0.05$). The RENAL scores for the study set are presented in Table 2.

Operative Outcomes

All surgeries were successful in the absence of conversion or transfusion. There were two patients who received RARPN and experienced postoperative complications. Of these, one was due to sudden low back pain on the third day after surgery. CT examination revealed renal hemorrhage, which was successfully controlled by selective renal artery embolization. The other was due to hypostatic pneumonia, which was successfully treated with atomization and anti-inflammatory treatment. There were six patients who developed postoperative complications post LRPN (two pulmonary infections, one wound infection, one fever, and two with delirium). Those with infections were successfully treated with anti-inflammatory treatment, whereas postoperative delirium was alleviated with conservative treatment. Four postoperative complications arose within the subset of the seven high-risk patients (RENAL score of ≥10) who underwent LRPN. By contrast, no postoperative complications arose in the three high-risk patients who underwent RARPN.

Table 2 RENAL nephrometry score

	RARPN	LRPN	*P* value
R (mean, range)	1.38 (1–3)	1.47 (1–3)	
E (mean, range)	1.65 (1–3)	1.63 (1–3)	
N (mean, range)	1.73 (1–3)	1.63 (1–3)	
A			
a (*n*)	11	19	
p (*n*)	6	14	
x (*n*)	9	24	
L (mean, range)	2.04 (1–3)	2.02 (1–3)	
H (*n*)	3	7	
Total score (mean ± SD, range)	6.8 ± 2.0	6.8 ± 1.7	0.972[a]
Complexity			
Low (score <7)	12	28	
Moderate (score 7–9)	11	22	
High (score ≥10)	3	7	

RARPN robot-assisted retroperitoneal partial nephrectomy, *LRPN* laparoscopic retroperitoneal partial nephrectomy, *R* radius (tumor size as maximal diameter), *E* exophytic/endophytic properties of the tumor, *N* nearness of tumor at deepest region to the collecting system or sinus, *A* anterior/posterior/*x* descriptor relative to the polar line, *L* location relative to the polar line, *H* hilar is assigned to tumors located near the main renal artery or vein

[a] Student's *t* test (unpaired)

The operative parameters and perioperative outcomes are presented in Table 3. The OTs (RARPN vs. LRPN, respectively) were 96.0 ± 16.9 vs. 110.0 ± 19.4 min ($P = 0.002$), WITs were 17.6 ± 3.1 vs. 22.8 ± 3.5 min ($P < 0.001$), and EBLs were 45 ± 15 vs. 97 ± 25 mL ($P < 0.001$). There were significant differences ($P < 0.05$) in the OTs, WITs, which were significantly shorter, and EBL, which was significantly less, of patients who underwent RARPN relative to those who received LRPN. No statistical significance was found in the drainage times (2.8 ± 2.5 vs. 3.3 ± 0.9 days, $P = 0.223$), intestinal recovery times (2.2 ± 0.6 vs. 2.6 ± 1.0 days, $P = 0.065$), hospital stay after surgery (8.3 ± 2.4 vs. 8.3 ± 2.8 days, $P = 0.960$), surgical complication rates ($P = 1.000$), or perioperative serum creatinine. The total cost of hospitalization was significantly higher ($P < 0.001$) for patients receiving RARPN (54,623.5 ± 6213.3 RMB) over LRPN (29,831.4 ± 5133.5 RMB).

Tumor Resection Histopathology

Histopathological analysis of the resected tumor revealed that there were 14 diagnoses of clear cell carcinoma, 1 of papillary renal cell carcinoma, 8 of angioleiomyolipomas, 1 of chromophobe renal cell carcinoma, 1 of inflammatory lesion, and 1 of organization of hematoma in those who underwent RARPN. Of those who received LRPN, 26 were diagnosed with angioleiomyolipomas, 20 with clear cell carcinoma, 5 with papillary renal cell carcinomas, 3 with cystic renal cell carcinomas, 1 with a renal cyst, 1 with an inflammatory lesion, and 1 with renal cell sarcoma. All resection margins were negative, and there was no evidence of local recurrence or distant metastasis during follow-up.

Table 3 Operative parameters and perioperative outcomes

	RARPN	LRPN	*P* value
WIT (mean ± SD, min)	17.6 ± 3.1	22.8 ± 3.5	<0.001[a]
OT* (mean ± SD, min)	96.0 ± 16.9	110.0 ± 19.4	0.002[a]
EBL (mean ± SD, mL)	45 ± 15	97 ± 25	<0.001[a]
Drainage time (mean ± SD, days)	2.8 ± 2.5	3.3 ± 0.9	0.223[a]
Intestinal recovery time (mean ± SD, days)	2.2 ± 0.6	2.6 ± 1.0	0.065[a]
Hospital stay after surgery (mean ± SD, days)	8.3 ± 2.4	8.3 ± 2.8	0.960[a]
Serum creatinine:			
Before surgery (mean ± SD, μmol/L)	70.9 ± 16.1	67.5 ± 10.2	0.248[a]
After surgery (mean ± SD, μmol/L)	77.5 ± 25.2	70.3 ± 10.1	0.065[a]
P value	0.060[b]	0.566[b]	
Perioperative complication (*n*)	2	6	1.000[c]
Hospitalization cost (mean ± SD, RMB)	54,623.5 ± 6213.3	29,831.4 ± 5133.5	<0.001[a]

RARPN robot-assisted retroperitoneal partial nephrectomy, *LRPN* laparoscopic retroperitoneal partial nephrectomy, *WIT* warm ischemia time, *OT* operating room time (excluding robot preparation time in RARPN group), *EBL* estimated blood loss

[a] *P* value: Student's *t* test (unpaired)

[b] *P* value: Student's t test (paired) for serum creatinine before and after operation in same group

[c] *P* value: chi-squared test

Discussion

Recent long-term clinical follow-up studies with large study sets have shown comparable outcomes in the use of NSS or radical nephrectomy in the treatment of small renal tumors, but the evidence alludes to a more favorable long-term survival in patients treated with NSS [7]. Furthermore, patients with the presence of a tumor in a solitary kidney or those susceptible to impaired renal function after radical nephrectomy undoubtedly require NSS. Patients with a unilateral renal carcinoma also showed evidence of contralateral benign renal disease (renal calculus and chronic pyelonephritis) and other diseases that cause renal deterioration or dysfunction (hypertension, diabetes mellitus, renal artery stenosis).

The recent emergence of RARPN has afforded surgeons with three-dimensional vision, seven degrees of freedom and scaling in the motion of surgical instruments, and a reduction in hand tremor and fatigue of the operator over conventional LRPN. Accordingly, NSS has become the gold-standard treatment for small renal tumors [8].

The RENAL algorithm is the most commonly used scoring system for renal tumors. With this system, tumors are scored according to their radius at maximal diameter (*R*), exophytic/endophytic properties (*E*), nearness of the deepest portion of tumor to the collecting system or sinus (*N*), anterior/posterior descriptor (*A*), and location relative to the polar line (*L*). The suffix *h* (hilar) is assigned to tumors that are close to the main renal artery or vein [9]. The RENAL score is traditionally applied to evaluate the complexity of renal tumors, but numerous studies have described its ability to predict the perioperative outcomes of patients undergoing NSS [10–15].

Moreover, novel applications have been described. Mullins et al. [16] showed that a high RENAL score was associated with high-grade pathology in a study of 886 patients treated with RARPN. Furthermore, Kopp et al. [17] observed that a high RENAL score (10–12) combined with transfusion status correlated with a shorter progression-free survival in a study of 202 patients with localized cT2 renal masses treated with RN or NSS. Kutikov et al. [4] created a novel nomogram for predicting high-grade histology by comparing the individual indices of the RENAL scoring system with the histology and grade of 525 resected tumors. In this analysis, high *R* and *L* scores were strongly associated with a high-grade histology. The study by Matsumoto et al. [18] showed a significant correlation between the *L* index and annual growth rates of renal masses scheduled for active surveillance. Nagahara et al. [9] noted that the RENAL score was a significant predictor of postoperative cancer recurrence. Of the RENAL score components, only the *L* component was strongly associated with recurrence-free survival. In addition to predicting perioperative complications of NSS, studies have highlighted that RENAL scoring can aid surgical planning in the treatment of renal tumors [19, 20]. Using the RENAL algorithm, Kutikov et al. [4] retrospectively scored 50 treated renal masses and grouped them by surgical treatment modality. They observed that low (4–6) and moderate (7–9) RENAL-scored tumors were more often treated with a partial nephrectomy, primarily using a minimally invasive approach, while high-complexity lesions (RENAL score 10–12) were more likely to undergo open partial or LRPN. Through retrospective analysis of 390 RENAL-scored cases of patients undergoing partial nephrectomy, Simhan et al. [21] unveiled that major complication rates differed among the tumor complexity groups (low risk vs. moderate risk vs. high risk 6.4 vs. 11.1 vs. 21.9%; $P = 0.009$).

Since the introduction of the Da Vinci robot at our institution, all patients undergo preoperative assessment with the RENAL algorithm. The present data on EBL, WIT, and OT show that RARPN performed superiorly to LRPN ($P < 0.05$), but other outcomes (drainage times, intestinal recovery times, hospital stay after surgery, surgical complication rates, and serum creatinine) were not statistically significant. It is important to note, however, that RARPN can achieve good outcomes and less operative complication in high-risk renal tumor patients (cT_1 and RENAL score ≥10). From our experience, we make the following recommendations and observations as enumerated. (1) If there are no contraindications, a retroperitoneal surgical approach should be recommended to patients, since this causes less disturbance to the abdominal cavity and the gut function returns more rapidly, effectively shortening the period of postoperative hospitalization. (2) To enable full retroperitoneal cavity manipulation by robot-assisted surgery with three manipulator arms, it is important to select the location of the trocar making the extension lines of the connection between two manipulative trocars (trocars 2 and 3) and the laparoscopic camera trocar, respectively, maintaining an intersection angle between the two extension lines of 120 to 135° and the distance of the two manipulative trocars (trocars 2 and 3) at >8 cm. (3) Cleaning the retroperitoneal fat along the ventral and dorsal side of the kidney to the iliac fossa is crucial to creating a larger operation space. (4) When planning the retroperitoneal approach, we recommend dissecting close to the lumbar major muscle from the dorsal region of the kidney. As such, injury to the peritoneum can be avoided, and the renal artery and posterior tumors can be accessed rapidly, effectively shortening the OT and minimizing intraoperative bleeding. (5) The biggest advantage of robot-assisted surgery is the accuracy afforded in saturation technique during suturing of the renal collection system and renal vessels and in the fixation of the renal parenchyma to the capsule.

However, the Da Vinci robot is expensive. Furthermore, each operation costs between 20,000 and 50,000 RMB. This prohibitive cost deters its widespread adoption, which in turn slows its potential development [22–24] However; robot-assisted laparoscopic surgery has more advantages than conventional open surgery and laparoscopic surgery, to which clinicians envisage that it will become a main surgical tool sometime in the future.

Conclusion

Numerous studies have confirmed that it is safe and feasible for tumors with a RENAL score >7 to undergo NSS [25]. In the present study, RARPN affords significant advantages in outcomes of WIT, EBL, and recovery time over conventional LRPN owing to an increased accuracy in excision and suturing. Furthermore, RARPN was successfully performed on high-risk patients with a RENAL score of ≥10 with without any operative complications. Compared with conventional laparoscopic surgery, we consider RARPN as more suitable for the surgical treatment of complex renal tumors (RENAL score ≥10), which is consistent with numerous studies elsewhere [26–28].

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they no conflict of interest.

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