Oncologic Outcomes and Safety Assessment of Retroperitoneal Laparoscopic Partial Nephrectomy versus Open Partial Nephrectomy in Treating Patients with Localized Renal Cell Carcinoma: A Propensity Score Matching Study

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AIM: Surgical intervention is crucial in radical resection of renal cell carcinoma (RCC). Different surgical procedures have different oncologic outcomes and safety in patients with RCC. Therefore, we aimed to investigate the oncologic outcomes and safety of retroperitoneal laparoscopic partial nephrectomy (RLPN) versus open partial nephrectomy (OPN) in treating patients with localized RCC.
METHODS: This retrospective cohort study included 160 patients with localized RCC who underwent either OPN or RLPN from January 2016 to June 2020. Out of these patients, 75 patients were treated with OPN and 85 patients were treated with RLPN. After propensity score matching, 130 patients (65 cases in each group) were finally included in the analysis. Additionally, surgical outcomes, three-year survival rates, and renal function parameters were assessed between the two groups, and the data were statistically analyzed using SPSS.
RESULTS: Compared to the OPN group, RLPN demonstrated significantly shorter surgical time, lower estimated blood loss ($p < 0.05$), and lower incidence of complications ($p = 0.024$). In contrast, the RLPN group had significantly longer warm ischemia time ($p = 0.011$) than the OPN group. Furthermore, there were no significant differences in three-year overall survival, disease-free survival, cancer specific survival rates, positive surgical margins, hospitalization time between the RLPN and OPN groups ($p > 0.05$). The incidence of complications in the RLPN group was significantly lower than that in the OPN group ($p = 0.024$). Postoperatively, creatinine level was significantly lower following RLPN at one year compared to OPN ($p = 0.029$).
CONCLUSIONS: RLPN offers advantages in surgical time, estimated blood loss, and postoperative complications, and it positively affects postoperative renal function, while OPN shows a shorter warm ischemia time. These two approaches result in comparable three-year survival rates. This study provides valuable insights into the oncologic outcomes and safety of RLPN compared to OPN in treating localized RCC.

Keywords: renal cell carcinoma; partial nephrectomy; laparoscopic surgery; oncologic outcomes; renal function; surgical complications

Introduction

Renal cell carcinoma (RCC) poses significant challenges in urologic oncology, making optimal surgical management crucial for achieving favorable oncologic outcomes while preserving renal function [1, 2]. While radical nephrectomy has been the traditional treatment for RCC, an increasing understanding of the disease has changed the focus toward nephron-sparing surgery for appropriately selected tumors [3]. Clinically, surgery remains the preferred and curative method for RCC, with nephron-sparing surgery being the gold standard for treating localized RCC [4]. This procedure can usually be performed through laparoscope or traditional open surgery. Open partial nephrectomy (OPN) has historically been the standard of care, providing direct access to the kidney for meticulous tumor resection [5]. However, retroperitoneal laparoscopic partial nephrectomy (RLPN) offers potential advantages, such as reducing surgical trauma, shortening the hospitalization period, and promoting postoperative recovery [6].

Despite the growing adoption of minimally invasive approaches like RLPN, this technique presents high technical requirements for surgeons and carries a considerable risk of complications. Hence, when treating localized RCC, it is essential to conduct comparative assessments of oncologic outcomes, safety, and renal function parameters for clinical decision-making. The rationale for comparing RLPN and OPN arises from the need to address critical considerations in the surgical management of localized RCC. The increasing utilization of RLPN in clinical practice warrants a thorough evaluation of its comparative effectiveness and safety compared to the well-established OPN [7, 8]. Given the potential differences in intraoperative variables, postoperative outcomes, and renal function parameters, a comprehensive comparative analysis is imperative to guide clinicians and patients in selecting the most appropriate surgical approach based on individual characteristics and disease status.

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This study aimed to comprehensively evaluate the oncologic outcomes and safety of RLPN versus OPN in treating localized RCC using a propensity score matching approach. By leveraging a robust retrospective cohort design, this study sought to compare the efficacy, safety, and renal function parameters in these two surgical approaches, providing valuable insights to guide clinical practice and inform future research endeavors.

Materials and Methods

Study Design

This retrospective cohort study included patients with localized RCC admitted to our hospital between January 2016 and June 2020. The patient data in this study were obtained from the electronic medical record database. However, there were several challenges, including a long inclusion time, missing data, and lost follow-up. To overcome these challenges, the propensity score matching method was adopted. Patients were then divided into two groups based on their surgical approach: the OPN group and the RLPN group.

This study was approved by the Institutional Review Board and Ethics Committee of Qingdao Central Hospital (approval no.: 20150127). The study design adhered to the Declaration of Helsinki [9] and informed consent was obtained from all participants.

Eligibility Criteria of Study Participants

Inclusion criteria were set as follows [10]: (1) Patients were diagnosed with localized RCC based on clinical symptoms, chest X-ray films, and abdominal ultrasound/computed tomographic (CT)/magnetic resonance imaging (MRI) examinations. (2) Patients with a renal nephrometry score of >6. (3) Patients with a tumor staged between pT1 and pT3a (tumor diameter <7 cm, without metastasis). (4) Patients with no relevant surgical contraindication. (5) Patients with normal cognitive function need to understand and cooperate with questionnaires. (6) Patients with complete case data.

However, exclusion criteria included (1) patients with severe organic lesions affecting the heart, liver, and lungs, or other malignant tumors, (2) those with impaired coagulation function and immune deficiency, (3) patients with hypertension and diabetes mellitus and (4) those with regional lymphatic metastases and distant metastases.

Using predetermined inclusion and exclusion criteria, 160 patients were finally included in the study cohort.

Treatment Approach

In the RLPN group, patients were positioned laterally following general anesthesia and cannula insertion. A 3 cm incision was made 2 cm above the midaxillary line and crista iliaca. The lumbodorsal fascia was bluntly dissected, and the retroperitoneal space was expanded using balloon inflation. Surgical incisions were made beneath the 12th rib along the posterior axillary line and the rib margin along the anterior axillary line, where the trocar and laparoscope were then placed. Artificial pneumoperitoneum was established with a CO_2 pressure of 15 mmHg. The extraperitoneal fat was removed, followed by a longitudinal incision into the Gerota fascia. The loose tissue between the renal fat capsule and the anemia capsule was dissected to expose the renal parenchyma and tumor. Subsequently, the renal pedicle and blood vessels were isolated, and the renal artery was clamped using a bulldog vascular clamp. The warm ischemia time was documented. The tumor and its surrounding renal parenchyma were removed 0.5–1 cm along the tumor margin. The renal collection system and the wound surface on the renal parenchyma were then sutured. A drainage tube was inserted near the renal artery, and the surgical incisions were sutured.

In the OPN group, patients were positioned laterally. An oblique incision was created either at the 11th rib or below the 12th rib to access the retroperitoneal space through meticulous dissection layer by layer. The subsequent procedures were similar to those followed in the case of RLPN.

Data Collection

The patient's demographics and tumor characteristics were retrieved from the medical records system. The data included age, sex, body mass index (BMI), hypertension, diabetes mellitus, Charlson comorbidity index, race, tumor size, tumor location, tumor stage, tumor type, multiple focus, Fuhrman nuclear grade, and renal nephrometry score. Furthermore, we recorded surgical data including procedure time, estimated blood loss, warm ischemia time, the rate of positive surgical margin, length of hospitalization, and postoperative complications, categorized using the Clavien-Dindo classification system [11]. Moreover, patients' oncologic outcomes were assessed by 3-year overall survival, disease-free survival, and cancer-specific survival rates after discharge. Additionally, safety evaluation was performed by comparing preoperative and postoperative renal function at one year, using blood indicators such as serum urea (UREA), creatinine (Cr), uric acid (UA), and estimated glomerular filtration rate (eGFR).

Charlson Comorbidity Index

The Charlson comorbidity index [12] was utilized to evaluate the severity of comorbidities in patients by categorizing 19 disease types, with each disease scored based on its severity. For instance, diseases like myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease or transient ischemic attack, dementia or Alzheimer's disease, chronic obstructive pulmonary disease or asthma, connective tissue disease, peptic ulcer, diabetes mellitus (without complications or end-organ damage) and being in the age group of 50–59 years were allocated 1 point. Moreover, diseases such as hemiplegia, moderate or severe chronic kidney disease, diabetes mellitus (with complications or end-organ damage), mild liver

Table 1. Demographics and baseline characteristics before propensity score matching.

Parameters	OPN (n = 75)	RLPN (n = 85)	t/χ^2	*p*-value
Age (years)	58.35 ± 4.15	60.24 ± 4.52	2.763	0.006
Sex (male/female)	35 (46.67%)/40 (53.33%)	55 (64.71%)/30 (35.29%)	5.269	0.022
BMI (kg/m^2)	24.96 ± 3.42	26.23 ± 2.89	2.514	0.013
Diabetes mellitus	19 (25.33%)	9 (10.59%)	6.000	0.014
Hypertension	11 (14.67%)	25 (29.41%)	4.968	0.026
Race (Han/Other)	69 (92.00%)/6 (8.00%)	71 (83.53%)/14 (16.47%)	2.614	0.106
Charlson comorbidity index	3.45 ± 1.26	2.96 ± 1.14	2.557	0.012
Tumor size (cm)	6.07 ± 1.61	6.73 ± 1.82	2.415	0.017
Tumor position (left/right)	40 (53.33%)/35 (46.67%)	41 (48.24%)/44 (51.76%)	0.414	0.520
Tumor location (Anterior/Posterior)	25 (33.33%)/50 (66.67%)	30 (35.29%)/55 (64.71%)	0.068	0.794
Tumor stage (pT1/pT2)	47 (62.67%)/28 (37.33%)	41 (48.24%)/44 (51.76%)	3.353	0.067
Tumor type (clear cell carcinoma /papillary/other) (%)	45 (60.00%)/21 (28.00%)/9 (12.00%)	60 (70.59%)/18 (21.18%)/7 (8.24%)	2.006	0.367
Multiple focus (%)	19 (25.33%)	14 (16.47%)	1.912	0.167
Fuhrman nuclear grade	2.84 ± 0.53	3.11 ± 0.64	2.884	0.004
Renal nephrometry score	8.45 ± 0.46	8.32 ± 0.51	1.684	0.094

OPN, open partial nephrectomy; RLPN, retroperitoneal laparoscopic partial nephrectomy; BMI, body mass index.

Table 2. Demographics and baseline characteristics after propensity score matching.

Parameters	OPN (n = 65)	RLPN (n = 65)	t/χ^2	*p*-value
Age (years)	59.72 ± 4.21	60.18 ± 3.95	0.646	0.519
Sex (male/female)	33 (50.77%)/32 (49.23%)	35 (53.85%)/30 (46.15%)	0.123	0.725
BMI (kg/m^2)	24.45 ± 2.54	24.72 ± 2.15	0.656	0.513
Diabetes mellitus	10 (15.38%)	7 (10.77%)	0.609	0.435
Hypertension	11 (16.92%)	14 (21.54%)	0.446	0.504
Race (Han/Other)	61 (93.85%)/4 (6.15%)	59 (90.77%)/6 (9.23%)	0.433	0.510
Charlson comorbidity index	3.12 ± 1.02	3.05 ± 0.98	0.405	0.687
Tumor size (cm)	6.71 ± 0.52	6.68 ± 0.49	0.339	0.736
Tumor position (left/right)	36 (55.38%)/29 (44.62%)	33 (50.77%)/32 (49.23%)	0.278	0.598
Tumor location (anterior/posterior)	20 (30.77%)/45 (69.23%)	26 (40%)/39 (60%)	1.211	0.271
Tumor stage (pT1/pT2)	43 (66.15%)/22 (33.85%)	40 (61.54%)/25 (38.46%)	0.300	0.584
Tumor type (clear cell carcinoma /papillary/other) (%)	44 (67.69%)/13 (20%)/8 (12.31%)	41 (63.08%)/17 (26.15%)/7 (10.77%)	0.706	0.703
Multiple focus (%)	11 (16.92%)	8 (12.31%)	0.555	0.456
Fuhrman nuclear grade	2.97 ± 0.42	3.05 ± 0.39	1.104	0.272
Renal nephrometry score	8.74 ± 1.43	8.69 ± 1.55	0.195	0.846

disease, solid tumor (without metastasis), leukemia, lymphoma, and being in the age group of 60–69 years were given 2 points. Moderate or severe liver disease and being aged 70–79 years were scored as 3 points, while being aged 80 years or older was assigned 4 points. Solid tumor (with metastasis) and acquired immune deficiency syndrome each received 6 points. The total score, ranging from 0–6 points, was calculated by summing the scores for each category. A higher total score indicated a more severe level of comorbidities in the patients.

Tumor Characteristics

Tumor pathological features were collected using a color ultrasound diagnostic instrument. Specifically, the ESAOTE Mylab30 color ultrasound diagnostic instrument was used with a dedicated laparoscopic probe (model LP323; batch no.: 20201124; manufacturer: Esaote Medical Equipment Co., Ltd.; location: Zhenjiang, China), with the outer diameter of 10 mm, frequency ranging from 5 to 10 MHz, probe face length of 35 mm, and width of 10 mm. The probe tip could be bent 90° in four axes (front, rear, left, and right) using the manipulation device on the handle. The probe was disinfected by immersing it in 2% glutaraldehyde for 30 minutes, followed by rinsing with saline solution. Subsequently, during laparoscopy, the paracolic gutter was opened along the colon, and the lateral peritoneum, perirenal fascia, and adipose capsule were dissected. Once the kidney was mobilized, the LUS probe was inserted through the laparoscopic sheath and placed directly on the renal surface for examination. The observations involved assessing the nature, size, and location of the tumor, and confirming multifocality. The entire LUS procedure was performed by

a sonographer, providing real-time interpretation of the ultrasound images in conjunction with the surgeons to facilitate the surgical procedure.

Fuhrman Nuclear Grade

The Fuhrman nuclear grade [13] is the most widely used nuclear grading system (Grade I to IV) for RCC, particularly for clear cell and papillary renal cell carcinomas.

- Grade I: At 400× magnification, nucleoli are not visible. The cell nuclei are uniformly round, with a diameter of <10 μm and indistinct nucleoli.
- Grade II: At 400× magnification, nucleoli are visible. The cell nuclei are enlarged and slightly irregular, with a diameter of up to 15 μm, and the nucleoli are distinct.
- Grade III: At 100× magnification, nucleoli are visible. The cell nuclei are highly irregular, with a diameter of up to 20 μm, and prominent large nucleoli are found.
- Grade IV: The cell nuclei are bizarre-shaped, with a diameter of 20 μm or more. Prominent large nucleoli, spindle-shaped cancer cells, and clumped nuclear chromatin are observed.

Renal Nephrometry Score

Renal nephrometry score [14] is a scoring system developed to assess renal masses based on specific anatomical features crucial for evaluating resectability. This scoring system utilizes the acronym R.E.N.A.L. to represent the following features: (R) Radius (tumor size), (E) Exophytic/endophytic properties, (N) Nearness to the collecting system or sinus, (A) Anterior/posterior descriptor, and (L) Location relative to the polar line. Four of these components are scored on a 1 to 3-point scale, while the 5th descriptor (A) designates whether the mass is primarily located anterior (a) or posterior (p) to the kidney's coronal plane.

Renal Function Indicators

After overnight fasting (10–12 hours), 5 mL fasting blood sample was collected at 7:00 in the morning. Serum Cr levels were determined using the Cr reagent kit (batch no.: 2014081732, Beijing Strong Biotechnologies, Beijing, China) and analyzed using the "Jaffe method". Serum UA concentration was assessed using the 640-A kit with urease-18 (Sigma–Aldrich Co., St. Louis, MO, USA). The UA levels were determined on the Advia 1650 Autoanalyzer (batch no.: 201805424; manufacturer: Siemens; location: Shanghai, China) employing the Fossati enzymatic reaction with uricase and a Trinder-like endpoint. The eGFR was calculated using the formula: eGFR = (140 – age) × body weight (kg) × 0.85 (for females)/[Scr (mg/dL) × 72], where Scr denotes serum creatinine.

Data Cleaning and Management

Before data analysis, a standardized data cleaning process was implemented to identify and rectify any inconsistencies, errors, or missing values. This process specifically involved a thorough examination of the dataset, the removal of duplicate entries, and the correction of data input errors.

Post-hoc Analysis

A post-hoc analysis was performed using G*Power 3.1.9.7, based on the option of "means: difference between two independent means (two groups)" under the *t*-test. The settings included selecting the two-tailed mode, setting the effect size (d) to 0.6, and the α error probability to 0.05. The sample sizes from both groups were entered to calculate the power (1- β error probability), yielding a value of 0.924.

Statistical Analyses

The data were analyzed using SPSS 29.0 statistical software (SPSS Inc., Chicago, IL, USA). A multivariable logistic regression model was utilized to calculate propensity scores for all patients. The covariates included age, sex, BMI, diabetes mellitus, hypertension, race, Charlson comorbidity index, tumor size, tumor location, tumor stage, tumor type, multiple focus, Fuhrman nuclear grade, and renal nephrometry score. A 1:1 matching procedure was conducted using the nearest neighbor method, with a caliper value of 0.2.

Moreover, categorical data, such as sex, race and tumor location, were expressed as [n (%)]. The chi-square test was applied using the basic formula when the sample size was ≥40 and the theoretical frequency (T) was ≥5, with the test statistic represented by χ^2. If the sample size was ≥40 but the theoretical frequency was between 1 and 5 ($1 \leq T < 5$), the chi-square test was adjusted using the correction formula. In cases where the sample size was <40 or the theoretical frequency was less than 1 (T <1), statistical analysis was conducted using Fisher's exact probability method.

Furthermore, continuous variables, such as age, tumor size, and surgical time were first assessed for normal distribution using the Shapiro-Wilk method. Normally distributed continuous variables were indicated as (Mean ± SD). Non-normally distributed variables were analyzed using the Wilcoxon rank-sum test and expressed as [median (25% quantile, 75% quantile)]. A p-value < 0.05 was considered statistically significant.

Results

Demographic and Basic Data

This study included 160 patients, comprising 75 patients treated with OPN and 85 undergoing RLPN (Table 1). Based on the propensity score matching, 65 patients who underwent OPN and 65 who underwent RLPN were included in the analysis (Table 2). There was no significant difference in mean age between the OPN and RLPN groups (59.72 ± 4.21 vs 60.18 ± 3.95; $t = 0.646$, $p = 0.519$). Similarly, the gender distribution was comparable between the two groups, with 50.77% male and 49.23% female in the OPN group and 53.85% male and 46.15% female in the RLPN group ($\chi^2 = 0.123$, $p = 0.725$). Furthermore, no sta-

Table 3. Comparison of surgical outcomes.

Parameters	OPN (n = 65)	RLPN (n = 65)	t/χ^2	*p*-value
Surgical time (min)	134.52 ± 16.32	127.22 ± 15.67	2.600	0.010
Estimated blood loss (mL)	230.34 ± 55.67	205.45 ± 38.89	2.955	0.004
Warm ischemia time (min)	19.92 ± 8.75	24.03 ± 9.36	2.584	0.011
Positive surgical margins (%)	2.35 ± 0.71	2.48 ± 0.68	1.076	0.284
Hospitalization time (days)	4.85 ± 1.32	4.98 ± 1.65	0.486	0.628
Complications (Clavien-Dindo ≥III)	11 (16.92%)	3 (4.62%)	5.123	0.024

tistically significant differences were observed in BMI, diabetes mellitus, hypertension, race, and Charlson comorbidity index between the two groups (all $p > 0.05$), as shown in Table 2. These findings suggested that the demographic and baseline characteristics were well-balanced between the two surgical approaches after propensity score matching.

Regarding tumor characteristics, the tumor size was 6.71 ± 0.52 cm in the OPN group and 6.68 ± 0.49 cm in the RLPN group, with no statistically significant difference ($t = 0.339$, $p = 0.736$). Additionally, there were no statistically significant differences in tumor position, tumor location, tumor stage, tumor type, multiple focus, Fuhrman nuclear grade, and renal nephrometry score between the two groups (all $p > 0.05$), as detailed in Table 2. These results indicated that after propensity score matching, the pathological characteristics were well-balanced between the two surgical approaches.

Surgical Outcomes

Following propensity score matching, significant differences were observed in the surgical outcomes between the OPN and RLPN groups. The RLPN group of patients showed a statistically significant reduction in surgical time (127.22 ± 15.67 min) compared to the OPN group (134.52 ± 16.32 min) ($t = 2.600$, $p = 0.010$). Additionally, the RLPN group had significantly lower estimated blood loss (205.45 ± 38.89 mL) compared to the OPN group (230.34 ± 55.67 mL) ($t = 2.955$, $p = 0.004$). In contrast, the warm ischemia time was significantly longer for RLPN (24.03 ± 9.36 min) compared to OPN (19.92 ± 8.75 min) ($t = 2.584$, $p = 0.011$). Furthermore, there was no significant difference in positive surgical margins, hospitalization time between the two surgical approaches ($p > 0.05$ for all comparisons), except for a significantly lower incidence of complications in the RLPN group (4.62%) compared to OPN (16.92%) ($\chi^2 = 5.123$, $p = 0.024$), as detailed in Table 3. These findings offered valuable insights into the comparative outcomes of the two surgical approaches.

Oncologic Outcomes

After propensity score matching, we assessed the oncologic outcomes for patients in both the OPN and RLPN groups. There were no statistically significant differences in the three-year overall survival rate, three-year disease-free survival rate, and three-year cancer-specific survival rate between the two groups (all $p > 0.05$, Table 4). These findings indicated comparable oncologic outcomes following the two surgical approaches.

Safety Evaluation

Following propensity score matching, the comparison of safety evaluation between the two groups revealed several findings. There were no statistically significant differences in eGFR, UA, Cr, and urea before surgery and eGFR and UA 1 year after surgery (all $p > 0.05$). However, one year postoperatively, patients who underwent RLPN showed a significantly lower Cr (174.19 ± 14.85 μmol/L vs 179.57 ± 12.94 μmol/L; $t = 2.204$, $p = 0.029$), significantly higher urea (4.42 ± 0.82 μmol/L vs 4.05 ± 0.85 μmol/L; $t = 2.515$, $p = 0.013$) compared to those who underwent OPN, as shown in Table 5. These results highlighted the comparative safety of the two surgical approaches at the one-year postoperative mark.

Discussion

The shorter surgical time and lower estimated blood loss after RLPN compared to OPN can primarily be attributed to the minimally invasive nature of laparoscopic surgery [15, 16]. RLPN involves smaller incisions and specialized instruments, resulting in better surgical field, meticulous tissue dissection, and improved hemostasis. These advantages contribute to reduced intraoperative blood loss and shorter surgical time than the open approach, as demonstrated in previous study [17]. Conversely, compared to OPN, RLPN results in a longer warm ischemia time, as the renal artery is clamped during partial nephrectomy, causing transient ischemia [18]. The longer warm ischemia time in RLPN is due to the need for multiple small incisions, which increases the complexity and difficulty of the procedure. This needs longer renal occlusion time to ensure a clear surgical field and smooth operation, ultimately resulting in prolonged warm ischemia time.

OPN offers direct access to the renal hilum, allowing for precise control of renal ischemia, potentially leading to shorter warm ischemia times than the laparoscopic approach [19, 20]. It is worth noting that although RLPN may be associated with longer warm ischemia time, the overall effect of this difference on postoperative renal function and oncologic outcomes may be limited in the case of appropri-

Table 4. Comparison of oncologic outcomes.

Parameters	OPN (n = 65)	RLPN (n = 65)	χ^2	*p*-value
3-year overall survival rate (%)	55 (84.62%)	57 (87.69%)	0.258	0.612
3-year disease-free survival rate (%)	52 (80%)	54 (83.08%)	0.204	0.651
3-year cancer-specific survival rate (%)	56 (86.15%)	59 (90.77%)	0.678	0.410

Table 5. Safety evaluation.

Parameters	OPN (n = 65)	RLPN (n = 65)	*t*	*p*-value
Preoperative eGFR (mL/min/1.73 m^2)	84.56 ± 6.74	85.21 ± 6.35	0.565	0.573
eGFR at postoperative 1 year (mL/min/1.73 m^2)	79.28 ± 5.09	79.36 ± 4.96	0.082	0.935
Preoperative UA (μmol/L)	252.98 ± 27.92	253.58 ± 32.12	0.113	0.911
UA at postoperative 1 year (μmol/L)	306.97 ± 47.28	302.72 ± 37.25	0.569	0.571
Preoperative Cr (μmol/L)	123.16 ± 13.45	124.89 ± 16.54	0.655	0.514
Cr at postoperative 1 year (μmol/L)	179.57 ± 12.94	174.19 ± 14.85	2.204	0.029
Preoperative urea (μmol/L)	4.13 ± 0.84	4.18 ± 1.05	0.319	0.750
Urea at postoperative 1 year (μmol/L)	4.05 ± 0.85	4.42 ± 0.82	2.515	0.013

eGFR, estimated glomerular filtration rate; UA, uric acid; Cr, creatinine.

ate selection of patients and skilled surgical teams [21, 22, 23].

This study found no significant difference in positive surgical margins, hospitalization time between the two surgical approaches. Each approach has its advantages and disadvantages. OPN provides a large operating space and significant anatomical landmarks and does not require manual establishment of pneumoperitoneum. However, it carries a higher risk of abdominal organ injury and can result in reduced recovery of gastrointestinal function after surgery. Conversely, RLPN comparatively carries a reduced risk of damage to abdominal organs, enhances recovery of gastrointestinal function and offers adequate vascular exposure with easier control. It also has the advantages of no contamination in abdominal cavity and low gastrointestinal adverse reactions. However, this approach has small operation space and lacks anatomical landmarks, contributing to the difference in complications. Despite these variations, it is crucial to note that the overall complication rates for both RLPN and OPN were relatively low, indicating the safety and feasibility of both approaches in treating localized RCC.

Furthermore, the analysis of oncologic outcomes revealed no significant differences between RLPN and OPN, suggesting comparable oncologic outcomes and long-term survival. These findings are consistent with Yoshida K *et al*. [24], who demonstrated equivalent oncologic outcomes for laparoscopic and open nephrectomy in the treatment of RCC. The comparable three-year overall survival, disease-free survival, and cancer-specific survival rates further support the clinical equipoise between RLPN and OPN in treating localized RCC.

Considering the effect on safety evaluation, our study found no significant difference in preoperative eGFR, UA, Cr, and urea levels between the two experimental groups, indicating similar preoperative renal function. Similarly, there were no significant differences in eGFR and UA at one year postoperatively between the two surgical approaches. RLPN is associated with significantly lower Cr at postoperative 1 year compared to OPN. Additionally, urea at postoperative 1 year was significantly lower for patients who underwent OPN compared to RLPN. These findings suggest potential differences in the effect of RLPN and OPN on renal function during the postoperative period, highlighting the importance of ongoing monitoring and assessment of renal function in patients undergoing different surgical approaches for RCC.

It is important to acknowledge the limitations of our study. As a retrospective cohort study, it is susceptible to inherent biases and limitations related to data collection, patient selection, and the potential for unmeasured confounders. Although propensity score matching was utilized to minimize confounding effects, the possibility of residual confounding cannot be entirely eliminated. Additionally, since the study was conducted at a single institution, the generalizability of the findings to broader patient populations and diverse healthcare settings should be interpreted with caution. Furthermore, the relatively limited sample size and follow-up duration may have impacted the statistical power and ability to detect small differences in outcomes between the two groups. Future research efforts should address these limitations through prospective, multi-institutional studies with larger sample sizes and longer-term follow-up periods.

Conclusions

This study confirms that RLPN offers advantages in surgical time, estimated blood loss, and postoperative complications, positively affecting postoperative renal function. Conversely, OPN shows a shorter warm ischemia time. The 3-year survival rates for the two methods are similar. These findings support the clinical equipoise between the two surgical approaches regarding oncologic outcomes, three-year

survival rates, and overall safety. While RLPN demonstrates advantages in reduced surgical time, estimated blood loss, and a lower incidence of postoperative complications, it is vital to consider the implications of longer warm ischemia time and potential differences in postoperative renal function. Hence, the surgical approach should be selected according to the specific circumstances of patients.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author Contributions

YMC and NX designed the study; all authors conducted the study; PJ and XYM collected and analyzed the data. YMC and PJ participated in drafting the manuscript, and all authors contributed to the critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board and Ethics Committee of Qingdao Central Hospital (approval no.: 20150127). The study design adhered to the Declaration of Helsinki and informed consent was obtained from all participants.

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Conflict of Interest

The authors declare no conflict of interest.

References

[1] Bahadoram S, Davoodi M, Hassanzadeh S, Bahadoram M, Barahman M, Mafakher L. Renal cell carcinoma: an overview of the epidemiology, diagnosis, and treatment. Giornale Italiano Di Nefrologia: Organo Ufficiale Della Societa Italiana Di Nefrologia. 2022; 39: 2022–vol3.

[2] Mendhiratta N, Muraki P, Sisk AE, Jr, Shuch B. Papillary renal cell carcinoma: Review. Urologic Oncology. 2021; 39: 327–337.

[3] Gurram S, Kavoussi L. Laparoscopic Partial Nephrectomy. Journal of Endourology. 2020; 34: S17–S24.

[4] Ebbing J, Menzel F, Frumento P, Miller K, Ralla B, Fuller TF, *et al*. Outcome of kidney function after ischaemic and zero-ischaemic laparoscopic and open nephron-sparing surgery for renal cell cancer. BMC Nephrology. 2019; 20: 40.

[5] Zeuschner P, Greguletz L, Meyer I, Linxweiler J, Janssen M, Wagenpfeil G, *et al*. Open versus robot-assisted partial nephrectomy: A longitudinal comparison of 880 patients over 10 years. The International Journal of Medical Robotics + Computer Assisted Surgery: MRCAS. 2021; 17: 1–8.

[6] Guo Y, Xu Q, Chen B, Liu L, Wang Y, Zhu A, *et al*. Clinical outcomes and effect on intraoperative blood loss and postoperative pain of patients undergoing retroperitoneal laparoscopic partial nephrectomy for complex renal tumors. World Journal of Surgical Oncology. 2021; 19: 282.

[7] Ng AM, Shah PH, Kavoussi LR. Laparoscopic Partial Nephrectomy: A Narrative Review and Comparison with Open and Robotic Partial Nephrectomy. Journal of Endourology. 2017; 31: 976–984.

[8] Calpin GG, Ryan FR, McHugh FT, McGuire BB. Comparing the outcomes of open, laparoscopic and robot-assisted partial nephrectomy: a network meta-analysis. BJU International. 2023; 132: 353–364.

[9] World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013; 310: 2191–2194.

[10] Li HM, Sun P, Yang WZ, Cui ZY. Impact of Curative Effect of Laparoscopic and Open Partial Nephrectomy for Complex Renal Tumours on Renal Function. Journal of the College of Physicians and Surgeons–Pakistan: JCPSP. 2019; 29: 958–961.

[11] Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, *et al*. The Clavien-Dindo classification of surgical complications: five-year experience. Annals of Surgery. 2009; 250: 187–196.

[12] Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of Chronic Diseases. 1987; 40: 373–383.

[13] Fuhrman SA, Lasky LC, Limas C. Prognostic significance of morphologic parameters in renal cell carcinoma. The American Journal of Surgical Pathology. 1982; 6: 655–663.

[14] Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. The Journal of Urology. 2009; 182: 844–853.

[15] Khoo HC, Lim LY, Shukor S, Zainal Adwin ZA, Zulkifli MZ, Fam XI. Initial experience of laparoscopic retroperitoneal partial nephrectomy in an academic hospital in Malaysia. The Medical Journal of Malaysia. 2022; 77: 764–767.

[16] Lu X, Guo Z, Yang G, Yang F, Sun Y, Zhang S, *et al*. A novel mini-retractor for retroperitoneal laparoscopic partial nephrectomy. Journal of Surgical Oncology. 2024; 129:

1407–1412.
[17] Muñoz-Rodríguez J, Prera A, Domínguez A, de Verdonces L, Rosado MA, Martos R, *et al*. Laparoscopic partial nephrectomy: Comparative study of the transperitoneal pathway and the retroperitoneal pathway. Actas Urologicas Espanolas. 2018; 42: 273–279.
[18] Deutch MR, Dreyer TK, Pelant T, Jensen JB. Impact of ischemia time during partial nephrectomy on short- and long-term renal function. Scandinavian Journal of Urology. 2023; 57: 86–89.
[19] Li KP, Wan S, Wang CY, Chen SY, Yang L. Perioperative, functional, and oncologic outcomes of robot-assisted versus open partial nephrectomy for complex renal tumors (renal score $\geq$7): an evidence-based analysis. Journal of Robotic Surgery. 2023; 17: 1247–1258.
[20] Lv Z, Chen G, Chen X, Li Y, Bao E, Hu K, *et al*. Open versus robot-assisted partial nephrectomy for highly complex renal masses: a meta-analysis of perioperitive and functional outcomes. Journal of Robotic Surgery. 2023; 17: 1955–1965.
[21] Singla N, Huang C, Benfante NE, Wong NC, Hakimi AA, Russo P. Open partial nephrectomy with kidney split: Effective surgical approach to resect completely endophytic tumors. Urologic Oncology. 2021; 39: 371.e1–371.e5.
[22] Wong R, Patel B, Biyani CS. Perioperative outcomes between laparoscopic versus open versus robotic partial nephrectomy: Current Review. Urologia. 2024; 91: 26–32.
[23] Dong J, Zhao Y, Xu W. Case Report: Retroperitoneal Laparoscopic Partial Nephrectomy for T2 Renal Cell Carcinoma During Pregnancy. Frontiers in Oncology. 2020; 10: 552228.
[24] Yoshida K, Kobari Y, Iizuka J, Kondo T, Ishida H, Tanabe K, *et al*. Robot-assisted laparoscopic versus open partial nephrectomy for renal cell carcinoma in patients with severe chronic kidney disease. International Journal of Urology: Official Journal of the Japanese Urological Association. 2022; 29: 1349–1355.