Comparison of Robotic Versus Laparoscopic Partial Nephrectomy For Renal Tumors With A RENAL Nephrometry Score ≥ 7 : A System Review and Meta-Analysis

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Research

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Abstract

Background To compare the perioperative outcomes of robotic partial nephrectomy (RPN) versus laparoscopic partial nephrectomy (LPN) for complex renal tumors with a RENAL nephrometry score ≥ 7 .

Methods We searched PubMed, EMBASE and the Cochrane Central Register for studies from 2000 to 2020 to evaluate the perioperative outcomes of RPN and LPN in patients with a RENAL nephrometry score ≥ 7 . We used RevMan 5.2 to pool the data.

Results Seven studies were acquired in our study. No significant differences were found in the estimated blood loss (WMD: 34.49; 95% CI: -75.16-144.14; $p=0.54$), hospital stay (WMD: -0.59; 95% CI: -1.24-0.06; $p=0.07$), positive surgical margin (OR: 0.85; 95% CI: 0.65-1.11; $p=0.23$), major postoperative complications (OR: 0.90; 95% CI: 0.52-1.54; $p=0.69$) and transfusion (OR: 0.72; 95% CI: 0.48-1.08; $p=0.11$) between the groups. RPN showed better outcomes in the operating time (WMD: -22.45; 95% CI: -35.06 to -9.85; $p=0.0005$), postoperative renal function (WMD: 3.32; 95% CI: 0.73-5.91; $p=0.01$), warm ischemia time (WMD: -6.96; 95% CI: -7.30-6.62; $p<0.0001$), conversion rate to radical nephrectomy (OR: 0.34; 95% CI: 0.17 to 0.66; $p=0.002$) and intraoperative complications (OR: 0.52; 95% CI: 0.28-0.97; $p=0.04$).

Conclusions RPN showed better perioperative clinical outcomes than LPN for the treatment of complex renal tumors with a RENAL nephrometry score ≥ 7 .

Background

Partial nephrectomy (PN) or nephron-sparing surgery (NSS) is considered the gold standard surgical strategy for clinical T1 renal tumors[1]. NSS can demonstrate equivalent oncologic outcomes and better postoperative renal function than radical nephrectomy. In 1993, Gill et al first introduced laparoscopic partial nephrectomy (LPN) in patients with a single renal tumor[2]. LPN has the advantage of reaching similar oncological outcomes, a shorter hospital stay and a lower estimated blood loss. Thus, LPN has been widely used for small renal tumors during the past decades[2-4]. Despite the different LPN techniques, several limitations exist, such as the requirement for technically demanding intracorporeal suture reconstruction skills and difficulty of tumor excision[5].

Robot-assisted partial nephrectomy was first reported in 2004 and has become a popular surgical method for clinical T1 renal tumors. The main advantages of the robotic system include the three-dimensional high-definition vision of the surgical field, a great range of wristed instruments, higher precision in the surgical dissection and easier intracorporeal sutured reconstruction, making RPN more popular than LPN[5-7]. Recently, Mari et al conducted a multicenter prospective study evaluating PN for complex renal tumors. They found that PN is safe for complex renal masses and acquired good oncological and functional results[8].

Several meta-analyses had reported two surgical methods for renal tumors[9-11]. Aboumarzouk et al. performed a meta-analysis including 717 patients comparing robotic partial nephrectomy (RPN) with laparoscopic partial nephrectomy (LPN). They found that RPN is a safe and feasible option for LPN[9]. Choi et al. conducted a meta-analysis including 23 studies involving 2,240 patients and found that RPN shows better recovery of postoperative renal function and a lower conversion rate to radical nephrectomy[11]. However, no meta-analysis has been performed to compare RPN and LPN in treating complex renal tumors with a RENAL nephrometry score ≥ 7 . This meta-analysis aimed to evaluate the perioperative, postoperative renal functional outcomes and oncological outcomes between RPN and LPN for complex renal tumors with a RENAL nephrometry score ≥ 7 .

Methods

Search strategy

We conducted this meta-analysis following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. We searched relevant studies in PubMed, EMBASE and the Cochrane Central Register published in English between 2000 and 2020. We used the following search terms: "robotic partial nephrectomy (RPN) [MeSH]", "laparoscopic partial nephrectomy (LPN) [MeSH]", "renal tumor* [MeSH]", and "RENAL nephrometry score ≥ 7 * OR complex renal tumors *". We also used the combined Boolean operators "AND" or "OR" in the title/abstract.

Inclusion and exclusion criteria

The eligible criteria were as follows: (1) comparative study of RPN and LPN to treat renal tumors with a RENAL nephrometry score ≥ 7 ; (2) reports with at least one of the following outcomes: estimated blood loss, hospital stay, intraoperative complications, postoperative complications, operative time, conversion rate to radical nephrectomy, positive surgical margin (PSM), transfusion, warm ischemia time, and postoperative renal function; (3) follow-up duration longer than 6 months; (4) the eGFR changes were evaluated in postoperative period, at least one week follow-up. The exclusion criteria were as follows: (1) case reports, reviews, editorial comments, meeting abstracts and articles without applicable data; (2) studies with insufficient data, such as missing SD (standard deviation) data and nonretrievable data; (3) studies that were not comparative and renal tumors with a RENAL score < 7 . The process of identifying relevant studies is summarized in Fig. 1. Two investigators (YLJ and XX) reviewed the articles.

Data extraction

The two authors extracted data, such as the estimated blood loss, operating time, positive surgical margin, postoperative complications, intraoperative complications, hospital stay, confusion, conversion rate to radical nephrectomy, postoperative renal function and warm ischemia time. The disagreements were resolved by the two reviewers (YLJ and XX).

Statistical analysis

We used Review Manager Version 5.2 software and the Mantel-Haenszel method (The Cochrane Collaboration, Oxford, UK) to conduct the data analysis. For quantitative data, we used the standard mean difference (SMD) and 95% confidence interval (CI) or weight mean difference (WMD) and 95% CI to pool continuous data. We used the odds ratio (OR) and 95% CI to calculate binary data. Cochran's Q test was used to evaluate the heterogeneity; $I^2 < 50\%$ or $P > 0.01$ was associated with little heterogeneity. Otherwise, $I^2 > 50\%$ or $P < 0.01$ was related to high heterogeneity. The statistical significance level was 0.05.

Quality assessment of the included studies

The New-Ottawa Scale (NOS) was used to evaluate the nonrandomized studies [12, 13]. The NOS scores were evaluated using a 9-point system. For randomized controlled trials, we assessed the risk of bias according to the Cochrane Collaboration handbook, version 5.0. Table 2 shows the quality assessment of the included studies.

Results

Seven studies were involved in our study [1, 7, 14–18]. The literature searching process is summarized in Fig. 1. From the PubMed, EMBASE and the Cochrane Central Register, we acquired 2,296 studies. After a precise search, we included 245 studies. After further processing, we excluded 104 studies. Finally, 7 studies meeting the inclusion criteria were included in this meta-analysis.

Operating time

Our study showed that there was significant difference in operating time between the RPN and LPN groups ($n=940$; 477 patients in the RPN group and 463 patients in LPN group; WMD: -22.45; 95% CI: -35.06 to -9.85; $I^2=85\%$; $p=0.0005$; random-effects model; Fig. 2).

Estimated blood loss

The estimated blood loss data were available in four studies. No statistically significant difference was found in the estimated blood loss between the RPN and LPN groups ($n=824$; 419 patients in the RPN group and 405 patients in the LPN group; WMD: 34.49; 95% CI: -75.16–144.14; $p=0.54$; random-effects model; Fig. 3).

Warm ischemia time

The warm ischemia time data were available in four studies. A statistically significant difference was found in the warm ischemia time between the RPN and LPN groups ($n=824$; 419 patients in the RPN group and 405 patients in the LPN group; WMD: -6.96; 95% CI: -7.30–-6.62; $p<0.0001$; $I^2=0$; random-effects model; Fig. 4).

Transfusion

Seven studies reported the transfusion in our meta-analysis. No statistically significant difference was found in the transfusion between the RPN and LPN groups ($n=1307$; 635 patients in the RPN group and 672 patients in the LPN group; OR: 0.72; 95% CI: 0.48–1.08; $p=0.11$; $I^2=0$; fixed-effective model; Fig. 5).

Conversion

The pooled data showed a statistically significant difference between the RPN and LPN groups ($n=1132$; OR: 0.34; 95% CI: 0.17 to 0.66; $I^2=53\%$; $p=0.002$; fixed-effects model; Fig. 6).

Hospital stay

Four studies reported hospital stay data in this study. No statistically significant difference was found in the hospital stay between the RPN and LPN groups ($n=824$; 419 patients in the RPN group and 405 patients in the LPN group; WMD: -0.59; 95% CI: -1.24–0.06; $p=0.07$; $I^2=86\%$; random-effects model; Fig. 7).

Intraoperative complications

Five studies reported the intraoperative complications. A statistically significant difference was found in the intraoperative complications between the RPN and LPN groups ($n=1040$; 527 patients in the RPN group and 513 patients in the LPN group; OR: 0.52; 95% CI: 0.28–0.97; $p=0.04$; $I^2=0$; fixed-effects model; Fig. 8).

Postoperative complications

Data on postoperative complications were available in seven studies. No statistically significant difference was found in the postoperative complications between the RPN and LPN groups ($n=1256$; 635 patients in the RPN group and 621 patients in the LPN group; OR: 0.85; 95% CI: 0.65–1.11; $p=0.23$; $I^2=0$; fixed-effective model; Fig. 9).

Postoperative renal function

Three studies were included in our meta-analysis to pool the postoperative renal function. A statistically significant difference was found in the postoperative function between the RPN and LPN groups ($n = 524$; 235 patients in the RPN group and 289 patients in the LPN group; WMD: 3.32; 95% CI: 0.73–5.91; $p=0.01$; $I^2 = 57$; random-effects model; Fig. 10).

Positive surgical margin

Six studies reported a positive surgical margin. No statistically significant difference was found in the positive surgical margin between the RPN and LPN groups ($n = 1132$; 573 patients in the RPN group and 559 patients in the LPN group; OR: 0.69; 95% CI: 0.27–1.78; $p=0.45$; $I^2=0$; fixed-effects model; Fig. 11).

Major postoperative complications

Seven studies were included in our meta-analysis to pool the major postoperative complications. No statistically significant difference was found in the major postoperative complications between the RPN and LPN groups ($n = 1212$; 615 patients in the RPN group and 597 patients in the LPN group; OR: 0.90; 95% CI: 0.52–1.54; $p=0.69$; $I^2 = 0$; fixed-effects model; Fig. 12).

Discussion

This meta-analysis is the first study to compare the perioperative outcomes and postoperative recovery renal function. We found no significant difference in the estimated blood loss, hospital stay, postoperative complication rate, positive surgical margin and transfusion between the RPN and LPN groups. The postoperative renal function, operating time, conversion rate to radical nephrectomy and warm ischemia time were lower in the RPN group than in the LPN group. In our meta-analysis, the pooled data of warm ischemia time indicated a shorter warm ischemia time in the RPN group than in the LPN group. Choi et al reported a similar outcome to ours ($p = 0.005$)[11].

Regarding the conversion rate to radical nephrectomy, our meta-analysis found that the RPN group had a lower conversion rate than the LPN group. However, Aboumarzouk et al conducted a meta-analysis including 717 patients and found that the conversion rate was not significantly different between the RPN and LPN groups ($p = 0.84$). The cause may be due to different baseline characteristics in different studies.

In our meta-analysis, the patients in the RPN group showed better recovery in the postoperative renal function than those in the LPN group. The RPN group showed a low warm ischemia time and a satisfactory postoperative eGFR rate. The postoperative renal function was thought to be associated with the duration of warm ischemia time. When the warm ischemia time was > 30 min, the postoperative eGFR rate decreased[19].

In our study, the warm ischemia time was lower in the RPN group than in the LPN group, causing quick renal function recovery. The cause may be attributed to using precise handling instruments, three-dimensional magnified vision and precise dissection of the renal pedicle, and better conducted tumor resection with robotic assistance. Kopp et al performed a study to analyze the related factors associated with postoperative renal function after partial nephrectomy. They found that the RENAL score could predict the estimated glomerular filtration rate and warm ischemia time[20]. In our meta-analysis, the pooled data of the warm ischemia time showed high heterogeneity. This finding may be related to the tumor location and surgeons with different surgical skills. Recently, Bertolo et al reported a study indicating that different reconstruction methods could shorten the ischemia and operating times[21]. The different suture skills may be the causes of high heterogeneity. Daniel et al found that prolonged warm ischemia time is related with worse perioperative outcomes[22]. However, a comparative study performed by Homayoun et al found that the prolonged warm ischemia time associated needs to be mitigated in RPN[23].

In our meta-analysis, we found that the operative time was shorter in the RPN group than in the LPN group. Choi et al performed a meta-analysis comparing RPN and LPN to treat renal tumors[11]. They found no significant difference between the two groups. This finding was not consistent with our study findings.

We found that intraoperative complications were lower in the RPN group than in the LPN group. However, Zhang et al found no significant difference between the groups ($p = 0.78$)[17]. Zhang et al performed a meta-analysis and found that the intraoperative complications showed no statistically significant difference between the groups[17]. In our study, we included patients with a RENAL nephrometry score ≥ 7 , which may explain the difference with Zhang's study. Additionally, different surgeons have different surgical skill levels for RPN or LPN.

Our meta-analysis also found that the positive surgical margin showed no statistically significant difference between the RPN and LPN groups ($p = 0.45$). Similarly, Zhang et al performed a meta-analysis and found no statistically significant difference between the RPN and LPN groups ($p = 0.61$). Aboumarzouk et al also reported a similar outcome ($p = 0.93$).

In our meta-analysis, the estimated blood loss showed no statistically significant difference between the RPN and LPN group. Zhang et al also found that the estimated blood loss exhibited no statistically significant difference between the groups ($p = 0.75$). This finding is consistent with our study findings. However, the high heterogeneity in the estimated blood loss was likely due to the difference in familiarity of surgeons to the surgical process. However, Chang et al also performed a propensity-score-matching study and found that RPN resulted in a significantly lower mean estimated blood loss than LPN ($p = 0.025$)[24]. Several systematic reviews and meta-analyses reported similar outcomes[9, 11, 25].

In our study, we reported that a statistically significant difference was found in the intraoperative complications between the RPN and LPN groups ($p = 0.04$). Similarly, Cacciamani et al performed a meta-analysis found that RPN was superior for intraoperative complications[26]. However, Gu et al. conducted a propensity score-based analysis indicated that no statistically significant difference was found between RPN and LPN groups[7].

Our study had several limitations. First, we did not include RCTs. This can lower the evidence of our study. Second, the included studies had different RENAL scores, which could increase the heterogeneity and lower the confidence of our meta-analysis. Additionally, the different studies reported variable tumor sizes and we did not balance these data, which could affect the warm ischemia time and postoperative renal function. We did not adjust the common baseline characteristics of patients. The different definitions of nomenclature and functional outcomes could lead to heterogeneity[27]. Third, we did not evaluate the oncological outcomes regarding overall survival, recurrence-free survival and cancer-specific survival. In our meta-analysis, some studies did not perform propensity score-based analysis, a finding that could increase the heterogeneity. Alimi et al conducted a multicenter study involving different surgeons that also increased the heterogeneity. Regarding high heterogeneity, we did not conduct sensitivity analysis or subgroup analysis. We also did not identify the causes of high heterogeneity. We compared the perioperative outcomes and postoperative renal function outcomes.

Conclusions

Our meta-analysis showed that RPN could achieve comparable outcomes in the estimated blood loss, hospital stay, operating time, positive surgical margin and transfusion. RPN achieves better outcomes in the postoperative renal function, warm ischemia time, conversion rate to radical nephrectomy and intraoperative complications. More RCTs should be performed to clarify the effectiveness of RPN and LPN.

Abbreviations

RPN: Robotic partial nephrectomy; LPN: laparoscopic partial nephrectomy

ESBL: estimated blood loss; CI: confidence interval; WMD: weight mean difference; OR: odds ratio;

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors Contributions

YLJ and ZJB designed the study. JBZ wrote the manuscript. YLJ, XX and STL analyzed the data. HXH, STL, JYL and ZJB searched the articles. All authors read and approved the final manuscript.

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Tables

Table1 Basic Characteristics of the Included Studies

Study	Year	Design	Sample Size		Mean age(years)		Tumor Size(cm)		BMI (kg/m ²)		RENAL score (sample size)	
			RPN	LPN	RPN	LPN	RPN	LPN	RPN	LPN	RPN	LPN
Long	2012	P,S	199	182	58.5	59.5	3.8 ^a	4.0 ^a	30.7 ^a	29.2 ^a	8.6	8.7
Jang	2014	R,S	89	38	49.1	54.7	3.0 ^a	2.5 ^a	24.3 ^a	25.3 ^a	7.8	7.5
Wang	2015	R,S	81	135	61.2	63.5	3.8 ^a	3.6 ^a	26.2 ^b	26.1 ^b	8.3 ^b	8.1 ^b
Gu	2018	R,S	96	96	51 ^b	50 ^b	4.8 ^b	4.8 ^b	25.9 ^b	25.6 ^b	8 ^b	8 ^b
Deng	2020	R,S	58	58	52.0	50.6	5.0	4.9	NA	NA	8 ^b	8 ^b
Alimi	2018	P,M	50	50	NA	NA	3.9	4.1	NA	NA	7.5 ^a	7.8 ^a
Zhang	2020	R,S	62	62	47	46	NA	NA	26	25	9 ^b	8 ^b

P prospective *S* single center *R* retrospective *NA* not available *BMI*/body mass index ^aMean ^bMedian *M* multiple

Table2 Newcastle-Ottawa Scale for risk of bias assessment of the included studies

Study Design		Selection				Comparability	Outcome			Total
		Representativeness of exposed cohort		Selective of nonexposed Cohort	Ascertainment of exposure		Assessment of outcome	Adequate follow-up length	Adequacy of follow-up	
Long	P	**		**		*	*	*	*	8
Jang	R	*		*	*	*	*	*	*	7
Wang	R	*		*	*	*	*	*	*	7
Gu	R	*		*	*	*	*	*	*	7
Deng	R	*		*	*	*	*	*	*	7
Alimi	P	**		**		*	*	*	*	8
Zhang	P	*		*		*	*	*	*	6

R Respective *P* Prospective

Figures

Figure 1

Flow diagram of the process for the selection of relevant studies.

Figure 2

Forest plot for operating time between the RPN and LPN.

Figure 3

Forest plot for estimated blood loss between the RPN and LPN.

Figure 4

Forest plot for warm ischemia time between the RPN and LPN.

Figure 5

Forest plot for transfusion between the RPN and LPN.

Figure 6

Forest plot for conversion between the RPN and LPN.

Figure 7

Forest plot for hospital stay between the RPN and LPN.

Figure 8

Forest plot for intraoperative complications between the RPN and LPN.

Figure 9

Forest plot for postoperative complications between the RPN and LPN.

Figure 10

Forest plot for postoperative renal function between the RPN and LPN.

Figure 11

Forest plot for postive surgical margin between the RPN and LPN.

Figure 12

Forest plot for major postoperative complications between the RPN and LPN.