Comparison by Pentafecta Criteria of Transperitoneal and Retroperitoneal Robotic Partial Nephrectomy for Large Renal Tumors

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Abstract

Objective: To compare and analyze surgical and functional outcomes of transperitoneal robotic partial nephrectomy (TRPN) and retroperitoneal robotic partial nephrectomy (RRPN) in localized renal tumors, including ≥ 4 cm renal masses.

Methods: Of 566 consecutive patients who underwent robotic partial nephrectomy by a single surgeon from December 2008 through July 2017, records for 523 patients who were preoperatively and 1 year postoperatively evaluated were analyzed for estimated glomerular filtration rate (eGFR). Primary endpoint was a comparison of Pentafecta criteria (negative surgical margin, no 30-day complications, warm ischemic time [WIT] ≤ 25 minutes, return of eGFR to $>90\%$ from baseline, and no upstaging of chronic kidney disease) between TRPN and RRPN. Secondary endpoint was finding predictors for Pentafecta achievement.

Results: In all 523 patients, these Pentafecta criteria were lower for RRPN than TRPN: operation time ($p < 0.001$), WIT ($p = 0.008$), and estimated blood loss ($p = 0.003$). In patients with ≥ 4 cm renal tumors, only operation time was faster in RRPN than TRPN ($p = 0.032$). RRPN demonstrated more eGFR decrease in all patients ($p = 0.006$) and patients with ≥ 4 cm renal tumors ($p = 0.008$). Pentafecta achievements, complications, and recurrences were not significantly different between TRPN and RRPN in all patients and patients with ≥ 4 cm renal tumors. Multivariable analysis revealed baseline hemoglobin ($p = 0.013$) and tumor size ($p < 0.001$) were predictive for Pentafecta achievement.

Conclusions: Pentafecta achievement was similar for TRPN and RRPN. Baseline hemoglobin and tumor size were predictors of Pentafecta achievement. RRPN was properly performed for anterolateral renal tumor.

Keywords: large renal tumors, robotic partial nephrectomy, Pentafecta criteria

Introduction

PARTIAL NEPHRECTOMY IS the standard treatment for localized T1 renal tumors when feasible and associated with lower incidence of chronic kidney disease (CKD) postoperatively than radical nephrectomy.¹ Multiple studies report that laparoscopic partial nephrectomy (LPN) provides similar oncologic outcomes to radical nephrectomy and fewer complications, including perioperative blood loss, compared with open partial nephrectomy (OPN). No differences are seen in overall and progression-free survival between LPN and OPN.^{2–4} Nevertheless, LPN has a surgical learning curve that can extend ischemic time and delay renal reconstruction. Robotic partial nephrectomy (RPN) demon-

strates better outcomes for warm ischemic time (WIT), estimated blood loss (EBL), and complication rates than LPN.^{5–9}

Recent studies report RPN is safe for cT1b renal tumors and has similar oncological outcomes and complications to cT1a renal tumors.^{10–12} The feasibility of RPN in patients with cT2a renal tumors is reported to be the same as for patients with cT1 renal tumors, including complications, positive margins, hospital stays, and decline of renal function.¹³

Both transperitoneal and retroperitoneal approaches are used in minimally invasive partial nephrectomy. Approach is mainly determined by the location of the renal mass. The transperitoneal approach is recommended for anterior or lateral tumors and the retroperitoneal approach is recommended for posterior or posterolateral tumors.¹⁴

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The retroperitoneal approach is performed in a confined space and therefore is more difficult, especially during LPN. In comparison, RPN has the advantages of a relatively transparent view and smaller devices by Endowrists on robotic instruments that stimulate and aid in the retroperitoneal approach.

By measuring perioperative and functional outcomes, the Pentafecta criteria could improve preservation of renal function after operation.¹⁵ Multiple studies compared Pentafecta outcomes after partial nephrectomy; however, only a single study compared transperitoneal robotic partial nephrectomy (TRPN) and retroperitoneal robotic partial nephrectomy (RRPN) using Pentafecta outcomes.¹⁶ We found no comparative study using Pentafecta criteria on large renal tumors.

In this study, we compared perioperative and functional outcomes using Pentafecta criteria for all patients and we investigated prognostic factors for Pentafecta achievement. Furthermore, outcomes of TRPN and RRPN for large renal tumors of cT1b and cT2a tumors were compared by Pentafecta criteria to determine the feasibility of RPN.

Methods

Patients and methods

After obtaining Institutional Review Board approval, we performed a retrospective chart review of consecutive 567 patients who underwent RPN by a single experienced surgeon from December 2008 through July 2017 in Samsung Medical Center. RPN was performed for patients with localized renal tumors of 10 cm or less without locally advanced or metastatic disease. Patients with single kidney, bilateral renal tumors, multifocal tumors, and insufficient patient data were excluded.

We evaluated the following clinical and perioperative data: age at surgery, sex, body mass index (BMI), American Society of Anesthesiology (ASA) score, history of hypertension or diabetes, tumor size, tumor laterality, baseline hemoglobin, preoperative and postoperative estimated glomerular filtration rate (eGFR), clinical T stage, type of surgical approaches (transperitoneal or retroperitoneal), operation time, WIT, EBL, and length of stay (LOS). Operation time was defined as the time from the beginning (incision) to end of procedure (closure of the skin). Preoperative abdominopelvic computed tomography images were analyzed in the axial and coronal planes. R.E.N.A.L nephrometry score was assigned and categorized as low (4–6 points), intermediate (7–9 points), or high (10–12 points) complexity. Pathologic results were histology, Fuhrman grade, and pathologic T stage. Intraoperative and postoperative complications were graded by Clavien classification and recurrences were categorized into local recurrence and distant metastasis.

Surgical approaches and technique

Both transperitoneal and retroperitoneal approaches were performed. Decisions about approach were mainly based on tumor location. RRPN was performed for posterior or lateral tumors and TRPN for anterior or hilar tumors. Previous surgical history, complexity, perpendicular location of tumors, and large amounts of perirenal fat on preoperative images heavily influenced the choice of approach.

Intravenous mannitol was routinely infused before tumor resection. Tumors were identified by intraoperative ultrasonography and tumor margins were scored with electrocautery by monopolar scissors. All surgeries proceeded with warm ischemia by clamping the main renal arteries with laparoscopic bulldog clamps without using the selective-clamp techniques in both approaches. After resection, surgical beds were continuously sutured with 3-0 V-Loc absorbable sutures (Covidien). Using a sliding-clip technique, renal parenchyma was continuously sutured with 2-0 polyglactin (Covidien).

Evaluation

The primary endpoint was a comparison of TRPN and RRPN by Pentafecta criteria between all patients and patients with ≥ 4 cm renal tumors. Pentafecta criteria were first described by Zargar et al. and consist of negative cancer margin, WIT ≤ 25 minutes, no complications, no CKD upstaging, and preservation of eGFR $>90\%$ from baseline.¹⁵ Preservation of eGFR was defined as ratio of eGFR at 9 to 12 months after operation to preoperative eGFR. CKD stage was defined by 2012 Kidney Disease: Improving Global Outcomes (KDIGO) Clinical Practice Guideline for the Evaluation and Management of CKD. CKD upstaging included upstaging to stage III, IV, or V.¹⁷ As a secondary endpoint, we compared Pentafecta outcomes of both approaches in patients with ≥ 4 cm renal tumors. Subgroup analyses of anterior and posterior tumors were evaluated in the same manner. As a secondary endpoint, predictive factors for Pentafecta achievement were evaluated using multivariable logistic regression analysis.

Statistics

Chi-square tests, Student's *t*-tests, and Mann-Whitney *U* tests were used for categorical and continuous variables. To compare preoperative and postoperative renal functional change, paired *t*-tests and Wilcoxon signed-rank tests were used. Multivariate cox regression analysis was used to find predictive factors for Pentafecta achievement. All tests were two sided, and *p*-values <0.05 were considered statistically significant. All statistical analyses were performed using SPSS Statistics 25.0 (IBM, Armonk, NY).

Results

Records for 523 patients undergoing TRPN ($n=310$) and RRPN ($n=213$) with median follow-up of 35 months were analyzed. No significant differences were seen between TRPN and RRPN patients in age, BMI, history of hypertension or diabetes, laterality, ASA grade, clinical T stage, tumor size, and RENAL nephrometry score. Only sex ($p=0.023$) and baseline hemoglobin were different ($p=0.004$). After categorization by RENAL nephrometry score complexity, no differences were found between TRPN and RRPN for proportion of simple (40.3% vs 43.7%), intermediate (53.5% vs 50.2%), and complex (6.1% vs 6.1%, $p=0.731$) scores. Analyses by separate RENAL nephrometry score domains revealed only domain A (anterior/posterior) was significantly different ($p=0.006$; "A" in Table 1). For pathological characteristics, tumor pathology and Fuhrman grade were not different; however, upstaging to pT3 stage was found for eight patients who received TRPN alone (2.6%) ("B" in

TABLE 1. BASELINE CHARACTERISTICS OF ALL PATIENTS

<i>Variables</i>	<i>TRPN (n=310)</i>	<i>RRPN (n=213)</i>	<i>p-Value</i>
<i>(A) Demographics and clinical characteristics</i>			
Age, years (median, IQR)	51 (42–58)	50 (41–58)	0.595
Sex, <i>n</i> (%)			
Male	197 (63.5)	156 (73.2)	0.023
Female	112 (36.5)	57 (26.8)	
Hypertension, <i>n</i> (%)	100 (32.3)	63 (29.6)	0.565
Diabetes, <i>n</i> (%)	34 (11.0)	29 (13.6)	0.412
BMI, kg/m ² (median, IQR)	25.2 (22.8–27.2)	25.0 (22.8–27.0)	0.542
Baseline Hb, g/dL (median, IQR)	14.4 (13.3–15.2)	14.8 (13.7–15.6)	0.004
Laterality, <i>n</i> (%)			
Right	152 (49.0)	112 (52.6)	0.476
Left	158 (51.0)	101 (47.4)	
ASA grade, <i>n</i> (%)			
1	135 (43.5)	90 (42.3)	0.951
2	168 (54.2)	118 (55.4)	
3	7 (2.3)	5 (2.3)	
Clinical T stage, <i>n</i> (%)			
cT1a	250 (80.6)	182 (85.4)	0.341
cT1b	57 (18.4)	29 (13.6)	
cT2a	3 (1.0)	2 (0.9)	
Tumor size, cm (median, IQR)	2.9 (2.2–3.7)	2.8 (2.0–3.5)	0.119
R.E.N.A.L score (median, IQR)	7 (6–8)	7 (6–8)	0.506
R.E.N.A.L score category			
Low (4–6)	125 (40.3)	93 (43.7)	0.731
Intermediate (7–9)	166 (53.5)	107 (50.2)	
High (10–12)	19 (6.1)	13 (6.1)	
R.E.N.A.L score domain “N”			
1	107 (34.5)	81 (38.0)	0.551
2	95 (30.6)	67 (31.5)	
3	108 (34.8)	65 (30.5)	
R.E.N.A.L score domain “A”			
Anterior	126 (40.6)	59 (27.7)	0.006
Posterior	85 (27.4)	79 (37.1)	
X	99 (31.9)	75 (35.2)	
<i>(B) Histopathology</i>			
Histology, <i>n</i> (%)			
Clear cell RCC	237 (76.5)	174 (81.7)	0.582
Papillary RCC	26 (8.4)	13 (6.1)	
Chromophobe RCC	20 (6.5)	14 (6.6)	
Other type RCC	4 (1.3)	2 (0.9)	
Benign	23 (7.4)	10 (4.7)	
Fuhrman grade, <i>n</i> (%)			
Low	151 (52.6)	109 (53.7)	0.854
High	136 (47.4)	94 (46.3)	
Pathological T stage, <i>n</i> (%)			
pT1a	255 (82.3)	190 (89.2)	0.025
pT1b	42 (13.5)	22 (10.3)	
pT2a	5 (1.6)	1 (0.5)	
pT3	8 (2.6)	0	

ASA=American Society of Anesthesiologists; BMI=body mass index; Hb=hemoglobin; IQR=interquartile range; RCC=renal cell carcinoma; RRPN=retroperitoneal robotic partial nephrectomy; TRPN=transperitoneal robotic partial nephrectomy.

Table 1). In these patients, six had cT1a stage, one had cT1b stage, and one had cT2a stage.

RRPN demonstrated lower operative time ($p<0.001$), WIT ($p=0.008$) and EBL ($p=0.003$) than TRPN. Patients undergoing TRPN and RRPN had similar LOS, baseline eGFR, and postoperative 1-year eGFR. The rate of eGFR change at 1 year postoperation was significantly lower in

RRPN ($p=0.006$; “A” in Table 2). Pentafecta achievement was similar for patients undergoing TRPN (34.5%) and RRPN (40.8%) ($p=0.167$). Pentafecta components were analyzed separately and WIT ≤ 25 minutes was the only discrete component (69.7% TRPN vs 77.9% RRPN, $p=0.045$). The rate of negative margins, absence of complications, eGFR recovery to $>90\%$ of preoperative eGFR,

TABLE 2. COMPARISON OF CLINICAL OUTCOMES IN ALL PATIENTS

Outcomes	TRPN (n = 310)	RRPN (n = 213)	p-Value
<i>(A) Perioperative outcomes</i>			
Operation time, minutes (median, IQR)	273 (230–314)	244 (202–295)	<0.001
WIT, minutes (median, IQR)	21 (16–27)	19 (15–25)	0.008
EBL, mL (median, IQR)	150 (100–200)	100 (60–200)	0.003
LOS, days (median, IQR)	9 (8–9)	9 (8–9)	0.891
Baseline eGFR, mL/min/1.73 m ² (mean ± SD)	86.1 ± 17.7	86.3 ± 15.2	0.779
Postoperative 1-year eGFR, mL/min/1.73 m ² (mean ± SD)	80.9 ± 17.8	78.4 ± 15.1	0.079
Changes of eGFR at 1 year postoperation, % (mean ± SD)	–5.4 ± 14.3	–8.7 ± 12.4	0.006
<i>(B) Pentafecta outcomes</i>			
Pentafecta achievement, n (%)	107 (34.5)	87 (40.8)	0.167
Pentafecta analysis, n (%)			
Negative margins	306 (98.7)	213 (100)	0.150
WIT ≤25 minutes	216 (69.7)	166 (77.9)	0.045
No complications	265 (85.5)	172 (80.8)	0.186
eGFR >90% of baseline	183 (59.0)	121 (56.8)	0.652
No CKD upstaging	274 (88.4)	194 (91.1)	0.385

CKD=chronic kidney disease; EBL=estimated blood loss; eGFR=estimated glomerular filtration rate; LOS=length of stay; SD=standard deviation; WIT=warm ischemic time.

and absence of CKD upstaging were comparable for the two approaches (“B” in Table 2).

Patients with ≥4 cm renal tumors were analyzed: 60 patients underwent TRPN and 31 underwent RRPN. No clinicopathological characteristics of patients with ≥4 cm renal tumors were different for the two approaches (Table 3). For patients with ≥4 cm renal tumors, operation time was shorter for RRPN ($p=0.032$), but WIT and EBL were not different. Baseline and 1 year postoperative eGFR were not significantly different between the two approaches. In patients with ≥4 cm renal tumors, changes in eGFR at 1 year postoperation were significantly lower at 1 year after RRPN ($p=0.008$; “A” in Table 4). Pentafecta achievement was not different ($p=0.428$). More TRPN patients had eGFR >90% of baseline than RRPN patients (51.7% vs 29.0%, $p=0.047$). The rate of negative margins, WIT ≤25 minutes, absence of complications, and absence of CKD upstaging were similar for both approaches (“B” in Table 4).

We performed subgroup analyses of patients with anterior and posterior renal tumors. Patients with anterior tumors had no differences in clinicopathological characteristics for the two approaches (Supplementary Table S1). EBL was significantly lower for RRPN ($p=0.037$) and other outcomes, including Pentafecta achievement, were similar for both approaches (Supplementary Table S2). Patients with posterior tumors were similar for both approaches, except for the clinicopathological characteristic of laterality (Supplementary Table S3). Operation time was significantly shorter in RRPN ($p<0.001$) and other outcomes, including Pentafecta achievement, were not different (Supplementary Table S4).

Intraoperative and postoperative complications are in Table 5. No differences were observed for all patients or for patients with ≥4 cm renal tumors. A case of conversion to radical nephrectomy and a case of conversion to open procedure were found for T1a patients during TRPN. For all patients, no differences were found in major complications (Clavien grade ≥3) between TRPN and RRPN. Neither blood transfusion ($p=0.629$) nor postoperative ileus showed differences for the two approaches ($p=0.274$; “A” in Table 5).

For patients with ≥4 cm renal tumors, no injury to other organs and no conversion to radical nephrectomy or open procedure were found. Furthermore, no patients had major complications with either approach (“B” in Table 5).

For all patients, follow-up duration was longer in RRPN patients ($p=0.007$). Recurrence was similar for both approaches ($p=0.830$). Recurrences occurred only in TRPN patients as a single local recurrence and three distant metastases (“A” in Table 6). In patients with ≥4 cm renal tumors, median follow-up durations were longer in RRPN patients; however, differences were not significant because of limited cohort numbers ($p=0.202$). Local recurrence and distant metastasis were single instances in TRPN patients (“B” in Table 6).

Multivariate logistic regression analysis was performed to find factors associated with Pentafecta achievement. We analyzed age, sex, history of hypertension or diabetes, BMI, baseline hemoglobin, tumor size, EBL, LOS, type of approach, tumor pathology, Fuhrman grade, and RENAL nephrometry score for domains E, N, A, and L. Multivariate analysis showed that baseline hemoglobin (odds ratio, OR [95% confidence interval, 95% CI] 1.182 [1.036–1.348], $p=0.013$) and tumor size (OR [95% CI] 0.641 [0.536–0.767], $p<0.001$) were associated with Pentafecta achievement. Type of approach (TRPN vs RRPN) ($p=0.141$) had no correlation (Table 7).

Discussion

To our knowledge, four studies reported Pentafecta results after RPN. Our study is the largest RPN series using Pentafecta criteria as well as the largest comparison of TRPN and RRPN ($n=523$). A single study compared TRPN and RRPN by Pentafecta criteria, but found variations in surgical procedures owing to multiple surgeons operating in two different centers.¹⁶

Trifecta criteria were generated by Hung and colleagues as WIT ≤25 minutes, negative surgical margins, and no urological complications.¹⁸ Pentafecta criteria added >90% preservation of baseline eGFR and no upgrading of CKD

TABLE 3. BASELINE CHARACTERISTICS OF PATIENTS WITH ≥ 4 CM RENAL TUMORS

<i>Variables</i>	<i>TRPN (n=60)</i>	<i>RRPN (n=31)</i>	<i>p-Value</i>
<i>(A) Demographics and clinical characteristics</i>			
Age, years (median, IQR)	50.0 (40.5–57.0)	53.0 (39.5–60.0)	0.752
Sex, n (%)			
Male	35 (58.3)	22 (71.0)	0.262
Female	25 (41.7)	9 (29.0)	
Hypertension, n (%)	20 (33.3)	10 (32.3)	0.918
Diabetes, n (%)	8 (13.3)	3 (9.7)	0.743
BMI, kg/m ² (median, IQR)	25.4 (23.3–27.8)	24.7 (22.6–28.5)	0.720
Baseline Hb, g/dL (median, IQR)	14.1 (13.0–15.2)	14.5 (13.5–15.5)	0.429
Laterality, n (%)			
Right	31 (51.7)	15 (48.4)	0.827
Left	29 (48.3)	16 (51.6)	
ASA grade, n (%)			
1	25 (41.7)	9 (29.0)	0.262
2	35 (58.3)	22 (71.0)	
Clinical T stage, n (%)			
cT1b	57 (95.0)	29 (93.5)	0.773
cT2a	3 (5.0)	2 (6.5)	
Tumor size, cm (median, IQR)	4.7 (4.3–5.4)	4.6 (4.3–5.0)	0.537
R.E.N.A.L score (median, IQR)	7 (6–8)	7 (6–8)	0.875
R.E.N.A.L score category			
Low (4–6)	18 (30.0)	10 (32.3)	0.945
Intermediate (7–9)	37 (61.7)	18 (58.1)	
High (10–12)	5 (8.3)	3 (9.7)	
R.E.N.A.L score domain “N”			
1	10 (16.7)	6 (19.4)	0.572
2	25 (41.7)	10 (32.3)	
3	25 (41.7)	15 (48.4)	
R.E.N.A.L score domain “A”			
Anterior	25 (41.7)	10 (32.3)	0.641
Posterior	20 (33.3)	11 (35.5)	
X	15 (25.0)	10 (32.3)	
<i>(B) Histopathology</i>			
Histology, n (%)			
Clear cell RCC	44 (73.3)	22 (71.0)	0.952
Papillary RCC	5 (8.3)	3 (9.7)	
Chromophobe RCC	6 (10.0)	4 (12.9)	
Other type RCC	1 (1.7)	1 (3.2)	
Benign	4 (6.7)	1 (3.2)	
Fuhrman grade, n (%)			
Low	23 (41.1)	12 (40.0)	0.924
High	33 (58.9)	18 (60.0)	
Pathological T stage, n (%)			
pT1a	16 (26.7)	10 (32.3)	0.705
pT1b	39 (65.0)	20 (64.5)	
pT2a	3 (5.0)	1 (3.2)	
pT3	2 (3.3)	0	

stage. Pentafecta achievement is considered composite measures of perioperative and functional outcomes.¹⁵ Zargar et al. analyzed 2392 cases of RPN and LPN in five high-volume centers by Pentafecta criteria; the rate of Pentafecta achievement for RPN was 38.5%.¹⁵ Our study found similar rates of Pentafecta achievement, with 34.5% for TRPN and 40.8% for RRPN for all patients. Kim and colleagues retrospectively analyzed 277 patients of renal cell carcinoma undergoing RPN and reported 38.3% of Pentafecta achievement for T1a patients and 26.7% for T1b patients.¹⁹ Our

study also analyzed patients with ≥ 4 cm renal tumors. Rates of Pentafecta achievement for patients with ≥ 4 cm renal tumors decreased to 25.0% in patients receiving TRPN and 16.1% for patients receiving RRPN. To find the reason for decreased Pentafecta achievement in patients with ≥ 4 cm renal tumors, Pentafecta criteria were analyzed separately. We found that rates of WIT ≤ 25 minutes were dissimilar for all patients and patients with ≥ 4 cm renal tumors. Moreover, in RRPN, preservation of eGFR $>90\%$ was discordant for all patients and patients with ≥ 4 cm renal tumors (65.8% for all

TABLE 4. COMPARISON OF CLINICAL OUTCOMES IN PATIENTS WITH ≥ 4 CM RENAL TUMORS

<i>Outcomes</i>			
<i>(A) Perioperative outcomes</i>	<i>TRPN (n=60)</i>	<i>RRPN (n=31)</i>	<i>p-Value</i>
Operation time, minutes (median, IQR)	310 (272–353)	269 (227–330)	0.032
WIT, minutes (median, IQR)	26 (21–30)	24 (21–29)	0.572
EBL, mL (median, IQR)	150 (100–200)	150 (100–275)	0.818
LOS, days (median, IQR)	9 (8–9)	9 (8–9)	0.487
Baseline eGFR, mL/min/1.73 m ² (mean $\pm$ SD)	85.2 $\pm$ 18.5	87.7 $\pm$ 17.7	0.546
Postoperative 1-year eGFR, mL/min/1.73 m ² (mean $\pm$ SD)	77.2 $\pm$ 17.5	72.5 $\pm$ 14.2	0.150
Changes of eGFR at 1 year postoperation, % (mean $\pm$ SD)	–8.3 $\pm$ 14.2	–16.5 $\pm$ 12.7	0.008
<i>(B) Pentafecta outcomes</i>			
Pentafecta achievement, n (%)	15 (25.0)	5 (16.1)	0.428
Pentafecta analysis, n (%)			
Negative margins	59 (98.3)	31 (100)	0.999
WIT ≤ 25 minutes	29 (48.3)	17 (54.8)	0.659
No complications	50 (80.3)	24 (77.4)	0.547
eGFR $> 90\%$ of baseline	32 (53.3)	9 (29.0)	0.045
No CKD upstaging	52 (86.7)	26 (83.9)	0.757

and 29.0% for patients with ≥ 4 cm renal tumors). However, this disparity did not appear for TRPN patients (59.0% for all and 51.7% for patients with ≥ 4 cm renal tumors). Therefore, TRPN could be more appropriate for achieving functional outcomes for patients with ≥ 4 cm renal tumors.

In secondary outcomes, baseline hemoglobin and tumor size were found to be independent predictive factors for Pentafecta achievement. Tumor size is a well-known factor

that affects surgical difficulty. However, baseline hemoglobin is a new finding about which further studies are needed.

Our study demonstrated high negative margin rates, with 98.7% for TRPN and 100% for RRPN, which were superior to previous results from high-volume institutions.^{20,21} A recent study of RPN reported low positive surgical margin rates, with 3.3% for cT1b renal tumors and 4.5% for cT2a renal tumors.¹³ Our results with patients with ≥ 4 cm renal

TABLE 5. THE DETAILS OF INTRAOPERATIVE AND POSTOPERATIVE COMPLICATIONS

<i>Complications</i>			
<i>(A) All patients</i>	<i>TRPN (n=310)</i>	<i>RRPN (n=213)</i>	<i>p-Value</i>
Intraoperative, n (%)	7 (2.3)	2 (0.9)	0.322
Blood transfusion	2 (0.6)	1 (0.5)	
Ureteral injury	0	1 (0.5)	
Small bowel injury	1 (0.3)	0	
Liver injury	2 (0.6)	0	
Conversion to radical nephrectomy	1 (0.3)	0	
Conversion to open procedure	1 (0.3)	0	
Postoperative, n (%)	41 (13.2)	39 (18.3)	0.138
Clavien grade 1	26 (8.4)	29 (13.6)	
Clavien grade 2	13 (4.2)	7 (3.3)	
Clavien grade 3	2 (0.6)	3 (1.4)	
Clavien grade 4	0	0	
Blood transfusion, n (%)	12 (3.9)	6 (2.8)	0.629
Ileus, n (%)	3 (1.0)	0	0.274
<i>Complications</i>			
<i>(B) Patients with ≥ 4 cm renal tumors</i>	<i>TRPN (n=60)</i>	<i>RRPN (n=31)</i>	<i>p-Value</i>
Intraoperative, n (%)	1 (1.7)	1 (3.2)	0.631
Blood transfusion	1 (1.7)	1 (3.2)	
Injury of other organs	0	0	
Surgical conversion	0	0	
Postoperative, n (%)	9 (15.0)	7 (22.6)	0.683
Clavien grade 1	4 (6.7)	4 (12.9)	
Clavien grade 2	5 (8.3)	3 (9.7)	
Clavien grade ≥ 3	0	0	
Blood transfusion, n (%)	4 (6.7)	3 (9.7)	0.686
Ileus, n (%)	2 (3.3)	0	0.546

TABLE 6. FOLLOW-UP DURATION AND RECURRENCE RATE

(A) All patients	TRPN (n=310)	RRPN (n=213)	p-Value
Follow up, months			
Mean $\pm$ SD	34.2 $\pm$ 25.6	38.3 $\pm$ 21.6	0.007
Recurrences, n (%)			
Local recurrence	1 (0.3)	0	0.394
Distant metastasis	3 (1.0)	0	
(B) Patients with ≥ 4 cm renal tumors	TRPN (n=60)	RRPN (n=31)	p-Value
Follow up, months			
Mean $\pm$ SD	32.5 $\pm$ 24.4	39.2 $\pm$ 21.7	0.202
Recurrences, n (%)			
Local recurrence	1 (1.7)	0	0.590
Distant metastasis	1 (1.7)	0	

tumors also demonstrated lower positive margin rates with 1.7% for TRPN and 0% for RRPN. These results could be attributable to a single skillful surgeon performing surgeries in our study.

Our study demonstrated significantly shorter operation times for RRPN than TRPN for all patients ($p < 0.001$) and patients with ≥ 4 cm renal tumors ($p = 0.032$). These findings were comparable to results from prior studies and were because of the advantages of directly approaching the kidney without bowel mobilization in the retroperitoneal approach.^{16,22–25}

RRPN was associated with benefits of shorter WIT ($p = 0.008$) and lower EBL ($p = 0.003$) in all patients, although no differences were seen in patients with ≥ 4 cm renal tumors. Shorter WIT and lower EBL could affect functional outcomes and are regarded as prominent factors in RPN. A single study described 307 mL less EBL for RRPN ($p < 0.01$), which widely uses earlier unclamping techniques in TRPN.²⁴ The initial 107 RPN cases (57 TRPN and 50 RRPN) at our institution from 2008 to 2012 were reported by Choo and associates, with RRPN demonstrating shorter operative times ($p = 0.015$) and WIT ($p = 0.04$) than TRPN. However, EBL was not significantly different ($p = 0.126$).²²

A meta-analysis reviewed eight studies on LPN and the retroperitoneal surgeries showed shorter LOS ($p < 0.001$), shorter operative times ($p < 0.001$), and lower EBL ($p = 0.042$) than the transperitoneal surgeries.²⁶ Nevertheless, retroperitoneal approach was not always associated with shorter LOS in RPN. Gin et al. and Kim et al. reported LOS benefits for RRPN. However, Stroup and colleagues reported no significant difference in LOS between the two approaches.^{16,27,28} Our study demonstrated no difference in LOS, possibly because of an absence of differences in perioperative complications, including ileus and blood transfusion. Also, RPN had the advantage of small Endowrists, which move easily when surgical space is limited, especially in retroperitoneal approach. They may contribute to less difference of complications and hospital stays between transperitoneal and retroperitoneal approaches in RPN.

Retrospective studies reported patients with cT2a tumors demonstrated less differences in eGFR at 12 months than patients with cT1 tumors after open, LPN and RPN.^{13,29} Before our study, however, no studies have compared reduction in eGFR after one postoperative year between TRPN and RRPN in patients with ≥ 4 cm renal tumors. In our study,

TABLE 7. MULTIVARIABLE LOGISTIC REGRESSION ANALYSIS OF FACTORS PREDICTING PENTAFECTA ACHIEVEMENT

Variables	Univariable			Multivariable		
	OR	95% CI	p-Value	OR	95% CI	p-Value
Age	0.989	0.974–1.004	0.145			
Sex (male vs female)	1.358	0.923–1.997	0.12			
Hypertension	0.779	0.528–1.149	0.207			
Diabetes	1.050	0.610–1.806	0.861			
BMI	1.015	0.963–1.069	0.585			
Baseline Hb	1.206	1.064–1.367	0.003	1.182	1.036–1.348	0.013
Tumor size	0.603	0.505–0.720	<0.001	0.626	0.522–0.750	<0.001
EBL	0.997	0.996–0.999	0.003	0.998	0.997–1.000	0.056
Types of approach (TRPN vs RRPN)	0.763	0.533–1.094	0.141			
Tumor pathology (RCC vs benign)	0.901	0.438–1.855	0.778			
Fuhrman grade (low vs high)	1.001	0.693–1.446	0.994			
R.E.N.A.L score domain “N”						
1	Reference			Reference		
2	0.885	0.578–1.356	0.575	1.139	0.724–1.792	0.573
3	0.507	0.327–0.788	0.003	0.693	0.434–1.105	0.123

CI=confidence interval; OR=odds ratio.

change in eGFR at 1 year postoperation was significantly more decreased at 1 year after RRPN than after TRPN for all patients ($p=0.006$) and patients with ≥ 4 cm renal tumors ($p=0.008$). In patients with ≥ 4 cm renal tumors, mean decrease in eGFR at 1 year postoperation was more than 10% for RRPN. In addition, TRPN demonstrated a higher rate of eGFR $>90\%$ of baseline than RRPN (51.7% vs 29.0%, $p=0.047$). Previous studies demonstrated that the transperitoneal approach had the advantage of sufficient surgical space as well as familiar anatomical sites.^{30–32} In comparison, confined surgical space created by a retroperitoneal approach potentially provoked difficulties in resecting large renal tumors with appropriate surgical margin lengths and suturing, which possibly injure the renal parenchyma. This may be attributable to the greater reduction of eGFR after RRPN.

In partial nephrectomy, a retroperitoneal approach has the advantage of avoiding the peritoneal cavity and having no impediment to the renal hilum, which results in less morbidity and faster recovery.^{33,34} Nevertheless, our study demonstrated no difference in perioperative complications, including transfusion and ileus, owing to the low incidence of complications of Clavien grade ≥ 2 , which was 4.8% for TRPN and 4.7% for RRPN.

We demonstrated notable findings in decision of approach. As in previous studies, TRPN was performed mainly for anterior tumors and RRPN for posterior tumors. Our study, however, determined that posterior tumors were 27.4% of TRPN cases and anterior tumors were 27.7% of RRPN cases. This prominence was a consequence of approach decisions by the surgeon, who preferred to operate on lateral tumors by RRPN and hilar tumors by TRPN. TRPN has been performed on posterior tumors with verified safety and effectiveness with no additional morbidity when comparing anterior or lateral tumors.³⁵ Maurice and associates reported a matched analysis of TRPN and RRPN for posterior tumors with 370 cases. TRPN and RRPN achieved similar outcomes with a slight benefit in LOS and WIT for RRPN.³⁶ We successfully operated on anterolateral tumors using RRPN and this might be attributable to the advantage of robotic surgery, including clear surgical view and small Endowrist.

This study has several limitations. The first is potential bias from the retrospective design and inclusion of only tertiary care patients in a single center. Second, renal scans were not examined for all patients. Therefore, differential renal functions could not be evaluated. Third, our median follow-up durations were 35 months and further long-term oncologic outcomes will be needed.

Despite these limitations, our study has the strength of including the largest number of Pentafecta studies after RPN and uniformity of a surgical procedure that has a learning curve, especially for RRPN. Our study supports a retroperitoneal approach for RPN, which demonstrated reliable functional outcomes for anterior as well as posterior renal tumors.

Conclusion

Pentafecta achievements were similar for TRPN and RRPN for all patients and patients with ≥ 4 cm renal tumors. Baseline hemoglobin and tumor size were predictive factors for Pentafecta achievement after RPN. In robotic surgery, a retroperitoneal approach could be suitable for anterolateral renal tumor.

Author Disclosure Statement

No competing financial interests exist.

Funding Information

This study was funded by a research grant from the National Research Foundation (NRF) of Korea, funded by the Ministry of Science and ICT (2017R1A2B4010568). This research was also supported by a grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (HI17C0025).

Supplementary Material

Supplementary Table S1
Supplementary Table S2
Supplementary Table S3
Supplementary Table S4

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Abbreviations Used

ASA = American Society of Anesthesiology
 BMI = body mass index
 CI = confidence interval
 CKD = chronic kidney disease
 EBL = estimated blood loss
 eGFR = estimated glomerular filtration rate
 LOS = length of stay
 LPN = laparoscopic partial nephrectomy
 OPN = open partial nephrectomy
 OR = odds ratio
 RPN = robotic partial nephrectomy
 RRPN = retroperitoneal robotic partial nephrectomy
 TRPN = transperitoneal robotic partial nephrectomy
 WIT = warm ischemic time