Comparison of Trifecta Outcome Among Open, Laparoscopic, and Robotic-Assisted Partial Nephrectomy in Patients With Small Renal Masses: 10-Year Experience in Ramathibodi Hospital

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Abstract

Purpose: To compare the trifecta outcome and perioperative and postoperative outcomes among open partial nephrectomy (OPN), laparoscopic partial nephrectomy (LPN), and robotic-assisted partial nephrectomy (RAPN) in patients with small renal masses in Ramathibodi Hospital.

Methods: We retrospectively reviewed 141 patients who underwent partial nephrectomy from January 2009 to December 2018. The baseline characteristics and preoperative outcomes were compared among the three surgical approaches.

Results: Among the 141 patients, 42 (29.79%), 29 (20.57%), and 70 (49.64%) patients underwent OPN, LPN, and RAPN, respectively. Among 116 patients with available data, 71 achieved the trifecta outcome [18 (56.25%), 14 (56.00%), and 39 (73.58%) in the OPN, LPN, and RAPN group, respectively; $p=0.276$]. The rate of conversion to OPN was higher in the LPN than RAPN group. The number of patients who received intraoperative packed red cells was lowest in the RAPN group. The estimated blood loss was significantly lower in the LPN group than OPN and RAPN groups ($p=0.041$). The operative time was shorter in the OPN group than LPN and RAPN groups ($p<0.001$). Multivariate analysis showed that the intraoperative complication rate was a predictive factor for trifecta outcome achievement.

Conclusion: OPN had the shortest operative time. LPN had the highest rate of conversion to OPN and lowest estimated blood loss. The number of patients who received intraoperative packed red cells was lowest in the RAPN group. However, achievement of the trifecta outcome was not significantly different among the three groups. The predictive factor for trifecta outcome achievement was the intraoperative complication rate.

Introduction

Renal cell carcinoma (RCC) accounts for 2–3% of all adult neoplasms. Approximately 64,000 new cases are diagnosed each year in the United States, and 14,400 patients die every year. In contrast, the incidence and mortality rate are approximately 50% lower in Asian-Americans/Pacific Islanders [1].

Renal masses may be either malignant or benign [2]. Small renal masses of < 4 cm are considered benign in 20–30% of cases [3]. Many clinical T1a cancers have an indolent biology [4]. The likelihood of malignancy increases with each 1-cm increase in diameter [5].

Common symptoms of renal masses are flank pain, a palpable mass, and hematuria. The incidental detection of renal masses [2] and the detection of small renal masses [6] have increased with improvements in imaging techniques [2].

Partial nephrectomy is being increasingly utilized for the treatment of renal masses [10]. The benefits of partial nephrectomy are improvement of morbidity and mortality, a decreased risk of development or

progression of chronic kidney disease (CKD), and similarity of oncologic outcomes compared with radical nephrectomy [7–10].

Urologic complications, such as urine leakage or postoperative bleeding, are more common after partial than radical nephrectomy [11]. Computed tomography with/without contrast or magnetic resonance imaging with/without gadolinium is recommended for investigation of renal masses [8, 12]. According to the 2017 American Urological Association guideline, partial nephrectomy is recommended for patients with cT1a renal masses and other conditions in which radical nephrectomy may compromise future renal function [8].

Partial nephrectomy is appropriate for patients with unilateral stage I to III tumors who have renal insufficiency, bilateral renal tumors, familial RCC, or a risk of progressive CKD because of young age or medical risk factors [12]. Open partial nephrectomy (OPN) was historically performed in all cases. However, laparoscopic partial nephrectomy (LPN) and robotic-assisted laparoscopic partial nephrectomy (RAPN) are now being increasingly used [13]. The first robot-assisted laparoscopic prostatectomy was performed in 2000 [14], and robotic-assisted renal surgery was performed thereafter. RAPN has been performed in Ramathibodi Hospital since 2015.

The concept of the “trifecta” outcome has recently been used to evaluate surgical proficiency and includes negative surgical margins, no severe surgical complications, and 90% preservation of the estimated glomerular filtration rate (eGFR) postoperatively [15]. However, the factors that affect the trifecta outcome are unclear. This study was performed to compare the perioperative, postoperative, and trifecta outcomes of OPN, LPN, and RAPN and identify predictive factors for trifecta outcome achievement.

Materials And Methods

Study population

We retrospectively reviewed the medical records of all patients who underwent OPN, LPN, and RAPN at Ramathibodi Hospital from January 2009 to December 2018. Patients with incomplete data were excluded. Informed consents were obtained from all subjects or, if subjects are under 18, from a parent and/or legal guardian.

The patients’ baseline characteristics and disease- and treatment-related parameters were collected, including age, sex, body weight, height, body mass index, previous abdominal surgery, American Society of Anesthesiologists classification, underlying disease, size of renal mass, RENAL nephrometry score (radius, endophytic vs. exophytic, nearness to collecting system, anterior or posterior, and location relative to polar line), surgical approach (OPN, LPN, or RAPN), tumor pathology, and preoperative serum creatinine concentration.

Perioperative and postoperative data were also collected, including the operative time (skin incision to skin closure time), estimated blood loss (EBL), blood transfusion, warm ischemia time, cold ischemia time, length of hospital stay (LOS), 1-year postoperative creatinine concentration and eGFR, and perioperative and postoperative complications. Trifecta outcome achievement was defined as the combination of negative surgical margins, no severe complications (Clavien–Dindo grade 0–2), and a postoperative eGFR of > 90% of the preoperative eGFR. All methods were carried out in accordance with relevant guidelines and regulations

Statistical analysis

Predictive factors for trifecta outcome achievement were compared between patients who did and did not achieve the trifecta outcome using Student's t-test or the Mann–Whitney test for continuous variables and the chi-square test or Fisher's exact test for categorical variables. The patients' characteristics, perioperative and postoperative outcomes, and trifecta outcome achievement were compared among the three operative techniques using one-way analysis of variance or the Kruskal–Wallis test for continuous variables and the chi-square test for categorical variables. Univariate and multivariate analyses were performed using a logistic regression model to identify predictive factors associated with CKD, a risk of severe complications, and trifecta outcome achievement. All statistical analyses were performed with Stata v.14 (StataCorp, College Station, TX, USA). Statistical significance was defined as a p-value of < 0.05.

Results

Among the 141 patients in this study, 42 (29.79%) underwent OPN, 29 (20.57%) underwent LPN, and 70 (49.64%) underwent RAPN (Table 1). The patients' characteristics were similar among the three groups in terms of sex, age, body mass index, underlying disease, previous abdominal surgery, American Society of Anesthesiologists classification, and tumor size on imaging. Tumor complexity according to the RENAL nephrometry score was significantly greater in the RAPN than OPN and LPN groups ($p = 0.005$).

Table 1
Patient characteristics according to type of operation

Patient characteristics	Total (n = 141)	OPN (n = 42)	LPN (n = 29)	RAPN (n = 70)	p-value
Sex					
Male	68 (48.23)	18 (42.86)	10 (34.48)	40 (57.14)	0.086
Female	73 (51.77)	24 (57.14)	19 (65.52)	30 (42.86)	
Age, years	56.68 ± 12.31	56.09 ± 13.22	58.55 ± 10.17	56.28 ± 12.65	0.658
BMI, kg/m ²	25.40 ± 4.28	25.38 ± 4.35	25.73 ± 4.55	25.28 ± 4.19	0.895
DM	26 (18.44)	9 (21.43)	7 (24.14)	10 (14.29)	0.432
HT	76 (53.90)	22 (52.38)	15 (51.72)	39 (55.71)	0.911
DLP	56 (39.72)	15 (35.71)	13 (44.83)	28 (40.00)	0.741
Chronic kidney disease					
Stage 1	74 (52.48)	18 (42.86)	15 (51.72)	41 (58.57)	0.477
Stage 2	42 (29.79)	16 (38.10)	9 (31.03)	17 (24.29)	
Stage 3a	14 (9.93)	4 (9.52)	3 (10.34)	7 (10.00)	
Stage 3b	7 (4.96)	3 (7.14)	2 (6.90)	2 (2.86)	
Stage 4	3 (2.13)	0 (0.00)	0 (0.00)	3 (4.29)	
Stage 5	1 (0.71)	1 (2.38)	0 (0.00)	0 (0.00)	
Single kidney	10 (7.09)	4 (9.52)	1 (3.45)	5 (7.14)	0.618
Previous abdominal surgery					
No	86 (60.99)	26 (61.90)	19 (65.52)	41 (58.57)	0.804
Yes	55 (39.01)	16 (38.10)	10 (34.48)	29 (41.43)	
Count previous abdominal surgery					
I	44 (80.00)	15 (93.75)	8 (80.00)	21 (72.41)	0.138

Data are presented as mean ± standard deviation, n (%), or median (interquartile range).

OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; eGFR, estimated glomerular filtration rate.

Patient characteristics	Total (n = 141)	OPN (n = 42)	LPN (n = 29)	RAPN (n = 70)	p-value
II	7 (12.73)	1 (6.25)	0 (0.00)	6 (20.69)	
III	3 (5.45)	0 (0.00)	1 (10.00)	2 (6.90)	
IV	1 (1.82)	0 (0.00)	1 (10.00)	0 (0.00)	
ASA class					
Class I	23 (16.31)	4 (9.52)	7 (24.14)	12 (17.14)	0.250
Class II	55 (39.01)	14 (33.33)	9 (31.03)	32 (45.71)	
Class III	60 (42.55)	22 (52.38)	13 (44.83)	25 (35.71)	
Class IV	3 (2.13)	2 (4.76)	0 (0.00)	1 (1.43)	
Side					
Left	65 (46.10)	17 (40.48)	12 (41.38)	36 (51.43)	0.451
Right	76 (53.90)	25 (59.52)	17 (58.62)	34 (48.57)	
Imaging size, mm	3.2 (2.3–4.8)	3.2 (2.1–6.0)	3.1 (2.3–4.1)	3.4 (2.3–4.8)	0.983
RENAL score					
Min–6	56 (39.72)	12 (28.57)	15 (51.72)	29 (41.43)	0.005
7–9	76 (53.90)	30 (71.43)	14 (48.28)	32 (45.71)	
10–12	9 (6.38)	0 (0.00)	0 (0.00)	9 (12.86)	
Pathologic mass size, cm (n = 134)	3 (2–5)	3 (2.2–5.5)	3 (2.2–5.5)	3 (2–4.2)	0.625
Pathology					
Renal cell carcinoma	70 (49.65)	18 (42.86)	11 (37.93)	41 (58.57)	0.204
Angiomyolipoma	54 (38.30)	18 (42.86)	16 (55.17)	20 (28.57)	
Oncocytoma	5 (3.55)	1 (2.38)	1 (3.45)	3 (4.29)	
Other	12 (8.51)	5 (11.90)	1 (3.45)	6 (8.57)	

Data are presented as mean $\pm$ standard deviation, n (%), or median (interquartile range).

OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; eGFR, estimated glomerular filtration rate.

Patient characteristics	Total (n = 141)	OPN (n = 42)	LPN (n = 29)	RAPN (n = 70)	p-value
Renal cell carcinoma (n = 68)					
Clear cell	55 (80.88)	12 (75.00)	8 (72.73)	35 (85.37)	0.146
Papillary	6 (8.82)	1 (6.25)	1 (9.09)	4 (9.76)	
Chromophobe	4 (5.88)	2 (12.50)	2 (18.18)	0 (0.00)	
Other	3 (4.41)	1 (6.25)	0 (0.00)	2 (4.88)	
Preoperative eGFR					
	90.7 (70.9–99.7)	79.7 (60.7–97)	86.9 (72.0–100.5)	93.1 (71.7–103)	0.375
Chronic kidney disease (n = 121)					
No	43 (35.54)	15 (42.86)	11 (39.29)	17 (29.31)	0.373
Yes	78 (64.46)	20 (57.14)	17 (60.71)	41 (70.69)	
Data are presented as mean ± standard deviation, n (%), or median (interquartile range).					
OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; eGFR, estimated glomerular filtration rate.					

The perioperative and postoperative outcomes are shown in Table 2. The LOS was similar in the OPN, LPN, and RAPN groups (5 days for all). The rate of conversion to radical nephrectomy was also similar among the three groups. The rate of conversion to OPN was significantly lower in the RAPN than LPN group. EBL was significantly lower in the LPN group than in the OPN and RAPN groups. The warm ischemia time was similar in the LPN and RAPN groups. The operative time was significantly shorter in the OPN group than in the LPN and RAPN groups. The numbers of patients who received perioperative and postoperative packed red cells (PRC) were significantly higher in the OPN group than in the LPN and RAPN groups.

Table 2
Perioperative and postoperative outcomes

Outcomes	Total (n = 141)	OPN (n = 42)	LPN (n = 29)	RAPN (n = 70)	p-value
Length of hospital stay, days	5 (4–6)	5 (4–6)	5 (4–7)	5 (4–6)	0.451
Conversion to RN					
No	135 (95.74)	41 (97.62)	29 (100)	65 (92.86)	0.338
Yes	6 (4.26)	1 (2.38)	0 (0.00)	5 (7.14)	
Conversion to open surgery					
No	139 (98.58)	42 (100)	27 (93.10)	70 (100)	0.041
Yes	2 (1.42)	0 (0.00)	2 (6.90)	0 (0.00)	
Estimated blood loss, mL	300 (150–500)	375 (200–700)	200 (100–400)	300 (150–500)	0.041
Warm ischemia time, min (n = 134)	20 (0–30)		27 (20–31)	25 (20–34)	-
Cold ischemia time, min (n = 134)	25 (0–35)	25 (0–35)			-
Operative time, min	190 (145–235)	125 (95–155)	175 (145–200)	220 (190–250)	0.000
Perioperative PRC					
No	117 (82.98)	29 (69.05)	25 (86.21)	63 (90.00)	0.015
Yes	24 (17.02)	13 (30.95)	4 (13.79)	7 (10.00)	
PRC, mL	283 (250–544)	267 (246–514)	283 (270–542)	288 (249–574)	0.763
PRC transfusion					
No	110 (78.01)	27 (64.29)	24 (82.76)	59 (84.29)	0.037
Yes	31 (21.99)	15 (35.71)	5 (17.24)	11 (15.71)	
PRC, mL	514 (257–783)	307 (246–860)	783 (515–864)	448 (270–540)	0.394
Margin (n = 136)					

Data are presented as median (interquartile range) or n (%).

OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; RN, radical nephrectomy; PRC, packed red cells; eGFR; estimated glomerular filtration rate.

Outcomes	Total	OPN	LPN	RAPN	p-value
	(n = 141)	(n = 42)	(n = 29)	(n = 70)	
Negative	127 (93.38)	37 (94.87)	25 (89.29)	65 (94.20)	0.614
Positive	9 (6.62)	2 (5.13)	3 (10.71)	4 (5.80)	
Intraoperative complications					
No	104 (73.76)	27 (64.29)	21 (72.41)	56 (80.00)	0.184
Yes	37 (26.24)	15 (35.71)	8 (27.59)	14 (20.00)	
Penetration of collecting system	29 (20.57)	14 (33.33)	6 (20.69)	9 (12.86)	
Conversion of operation	8 (5.67)	1 (2.38)	2 (6.90)	5 (7.14)	
Postoperative complications (Clavien–Dindo)					
Grade 0–1	106 (75.18)	33 (78.57)	23 (79.31)	50 (71.43)	0.922
Grade 2	29 (20.57)	6 (14.29)	6 (20.69)	17(24.29)	
Grade 3a	2 (1.42)	1 (2.38)	0 (0.00)	1 (1.43)	
Grade 4a	2 (1.42)	1 (2.38)	0 (0.00)	1 (1.43)	
Grade 4b	2 (1.42)	1 (2.38)	0 (0.00)	1 (1.43)	
Readmission	3 (2.14)	1 (2.44)	0 (0.00)	2 (2.86)	0.999
eGFR					
1.0–1.5 years	86.2 (63.4–95.1)	76.2 (55.5–90.8)	85.5 (68.3–96.0)	87.9 (69.8–96.0)	0.290
Data are presented as median (interquartile range) or n (%).					
OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; RN, radical nephrectomy; PRC, packed red cells; eGFR; estimated glomerular filtration rate.					

The pathologic data in the OPN, LPN, and RAPN groups were similar in terms of the tumor size, negative margin rate, and rate of RCC, with no significant differences as shown in Table 3.

Table 3
Trifecta outcome

Data	Total (n = 141)	OPN (n = 42)	LPN (n = 29)	RAPN (n = 70)	p-value
Achieved eGFR at 1 year (n = 121)					
< 90%	78 (64.46)	20 (57.14)	17 (60.71)	41 (70.69)	0.373
≥ 90%	43 (35.54)	15 (42.86)	11 (39.29)	17 (29.31)	
Margin (n = 136)					
Negative	127 (93.38)	37 (94.87)	25 (89.29)	65 (94.20)	0.614
Positive	9 (6.62)	2 (5.13)	3 (10.71)	4 (5.80)	
Severe complications (Clavien–Dindo grade 3–6)					
No	135 (95.74)	39 (92.86)	29 (100)	67 (95.71)	0.342
Yes	6 (4.26)	3 (7.14)	0 (0.00)	3 (4.29)	
Trifecta outcome (n = 116)					
No	45 (38.79)	14 (43.75)	13 (48.15)	18 (31.58)	0.276
Yes	71 (61.21)	18 (56.25)	14 (51.85)	39 (64.42)	
Data are presented as n (%).					
OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; eGFR, estimated glomerular filtration rate.					

With respect to intraoperative complications, the incidence of collecting system perforation and severe complications (Clavien–Dindo grade 3–6) were similar among the three groups. The proportions of patients who achieved ≥ 90% preservation of the eGFR at 1 year postoperatively were also similar among the three groups, as shown in Table 4.

Table 4
Numbers of patients who achieved trifecta outcome

	OPN	LPN	RAPN
Achieved $\geq 90\%$ eGFR at 1 year	15/35 (42.86)	11/28 (39.29)	17/58 (29.31)
Negative margin	37/39 (94.87)	25/28 (89.29)	65/69 (94.2)
No severe complications	39/42 (92.86)	29/29 (100)	67/70 (95.71)
Achieved trifecta outcome	18/32 (56.25)	14/27 (51.85)	39/57 (64.42)
Data are presented as n (%).			
OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN, robot-assisted partial nephrectomy; eGFR, estimated glomerular filtration rate			

Because of incomplete data in 25 patients, 116 patients were included in the trifecta outcome analysis. The proportion of patients who achieved the trifecta outcome was similar among the three groups, as shown in Table 5.

Table 5
Patient characteristics according to achievement of trifecta outcome

Patient characteristics	Total (n = 116)	Non-Trifecta (n = 45)	Trifecta (n = 71)	p-value
Sex				
Male	60 (51.72)	30 (66.67)	30 (42.25)	0.010
Female	56 (48.28)	15 (33.33)	41 (57.75)	
Age, years	57.40 ± 11.61	57.93 ± 12.67	57.07 ± 10.96	0.698
BMI, kg/m ²	25.16 ± 4.27	25.81 ± 3.97	24.75 ± 4.44	0.196
DM	20 (17.24)	11 (24.44)	9 (12.68)	0.102
HT	61 (52.59)	24 (53.33)	37 (52.11)	0.898
DLP	44 (37.93)	17 (37.78)	27 (38.03)	0.978
Chronic kidney disease				
Stage 1	62 (53.45)	18 (40.00)	44 (61.97)	0.088
Stage 2	35 (30.17)	17 (37.78)	18 (25.35)	
Stage 3a	11 (9.48)	7 (15.56)	4 (5.63)	
Stage 3b	6 (5.17)	3 (6.67)	3 (4.23)	
Stage 4	1 (0.86)	0 (0.00)	1 (1.41)	
Stage 5	1 (0.86)	0 (0.00)	1 (1.41)	
Single kidney	7 (6.03)	1 (2.22)	6 (8.45)	0.245
Previous abdominal surgery				
No	72 (62.07)	29 (64.44)	43 (60.56)	0.675
Yes	44 (37.93)	16 (35.56)	28 (39.44)	
Count previous abdominal surgery				
I	35 (79.55)	11 (68.75)	24 (85.71)	0.390

Data are presented as n (%), mean ± standard deviation, or median (interquartile range).

BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.

Patient characteristics	Total (n = 116)	Non-Trifecta (n = 45)	Trifecta (n = 71)	p-value
II	6 (13.64)	3 (18.75)	3 (10.71)	
III	2 (4.55)	1 (6.25)	1 (3.57)	
IV	1 (2.27)	1 (6.25)	0 (0.00)	
ASA class				
Class I	22 (18.97)	5 (11.11)	17 (23.94)	0.105
Class II	44 (37.93)	17 (37.78)	27 (38.03)	
Class III	48 (41.38)	21 (46.67)	27 (38.03)	
Class IV	2 (1.72)	2 (4.44)	0 (0.00)	
Side				
Left	50 (43.10)	19 (42.22)	31 (43.66)	0.879
Right	66 (56.90)	26 (57.78)	40 (56.34)	
Size, mm	3.2 (2.3–4.8)	3.2 (2.2–4.8)	3.4 (2.6–4.8)	0.182
RENAL score	7 (6–8)	7 (6–8)	8 (7–10)	0.324
RENAL score group				
Min–6	45 (38.79)	17 (37.78)	28 (39.44)	0.641
7–9	66 (56.90)	25 (55.56)	41 (57.75)	
10–12	5 (4.31)	3 (6.67)	2 (2.82)	
Length of hospital stay, days	5 (4–6)	5 (4–6)	9 (4–11)	0.000
Warm ischemia time, min (n = 111)	20 (0–30)	20 (0–30)	25 (10–30)	0.905
Cold ischemia time, min (n = 111)	0 (0–0)	0 (0–0)	0 (0–17.5)	0.109
Operative time, min	190 (145–235)	185 (145–230)	242 (185–285)	0.321
Perioperative PRC				

Data are presented as n (%), mean ± standard deviation, or median (interquartile range).

BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.

Patient characteristics	Total (n = 116)	Non-Trifecta (n = 45)	Trifecta (n = 71)	p-value
No	97 (83.62)	36 (80.00)	61 (85.92)	0.402
Yes	19 (16.38)	9 (20.00)	10 (14.08)	
PRC, mL	283 (252–448)	284 (256–594)	274 (243–307)	0.327
PRC transfusion				
No	92 (79.31)	34 (75.56)	58 (81.69)	0.427
Yes	24 (20.69)	11 (24.44)	13 (18.31)	
PRC, mL	377 (258–687)	780 (256–864)	282 (260–448)	0.034
Pathologic mass size, cm (n = 113)	3 (2–5)	3 (2–5)	3.8 (2.6–5.0)	0.261
Margin				
Negative	109 (93.97)	38 (84.44)	71 (100)	0.001
Positive	7 (6.03)	7 (15.56)	0 (0.00)	
Pathology				
Renal cell carcinoma	59 (50.86)	23 (51.11)	36 (50.70)	0.700
Angiomyolipoma	43 (37.07)	15 (33.33)	28 (39.44)	
Oncocytoma	5 (4.31)	3 (6.67)	2 (2.82)	
Other	9 (7.76)	4 (8.89)	5 (7.04)	
Renal cell carcinoma (n = 68)				
Clear cell	46 (77.97)	16 (69.57)	30 (83.33)	0.623
Papillary	6 (10.17)	3 (13.04)	3 (8.33)	
Chromophobe	4 (6.78)	2 (8.70)	2 (5.56)	
Other	3 (5.08)	2 (8.70)	1 (2.78)	
Intraoperative complications				
No	89 (76.72)	28 (62.22)	61 (85.92)	0.003

Data are presented as n (%), mean $\pm$ standard deviation, or median (interquartile range).

BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.

Patient characteristics	Total (n = 116)	Non-Trifecta (n = 45)	Trifecta (n = 71)	p-value
Yes	27 (23.28)	17 (37.78)	10 (14.08)	
Creatinine				
Preoperative	0.87 (0.68–1.09)	0.86 (0.67–1.06)	1.60 (1.48–2.50)	0.010
2–4 weeks	0.97 (0.71–1.22)	0.95 (0.70–1.19)	1.99 (1.52–2.10)	0.003
eGFR				
Preoperative	90.7 (70.9–99.7)	92.3 (72.0–100.6)	36.3 (28.0–53.5)	0.046
2–4 weeks	77.9 (58.5–94.9)	78.4 (60.3–96.0)	28.0 (22.0–52.7)	0.017
1–3 months	86.8 (63.1–97.7)	87.2 (64.6–98.2)	43.1 (18.1–50.6)	0.003
Operation type				
OPN	32 (27.59)	14 (31.11)	18 (25.35)	0.276
LPN	27 (23.28)	13 (28.89)	14 (19.72)	
RAPN	57 (49.14)	18 (40.00)	39 (54.93)	
Data are presented as n (%), mean ± standard deviation, or median (interquartile range).				
BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.				

In the univariate analysis, the factors that affected the trifecta outcome were male sex, LOS, rate of intraoperative complications, and rate of postoperative complications. In the multivariate analysis, the factors that affected the trifecta outcome were the LOS and rate of intraoperative complications, as shown in Table 6.

Table 6
Predictive factors for achievement of trifecta outcome

Predictive factors	Univariate OR (95%CI)	p-value	Multivariate OR (95%CI)	p-value
Sex				
Male	1			
Female	2.733 (1.25–5.95)	0.011		
Age (years)	0.993 (0.96–1.02)	0.696		
BMI (kg/m ²)	0.943 (0.86–1.03)	0.197		
DM	0.448 (0.16–1.18)	0.107		
HT	0.952 (0.45–2.01)	0.898		
DLP	1.011 (0.46–2.18)	0.978		
Chronic kidney disease				
Stage 1	1			
Stage 2	0.433 (0.18–1.02)	0.057		
Stage 3a	0.233 (0.06–0.89)	0.034		
Stage 3b	0.409 (0.07–2.22)	0.300		
Stage 4	-			
Stage 5	-			
Single kidney	4.061 (0.47–34.91)	0.202		
Previous abdominal surgery				
No	1			
Yes	1.180 (0.54–2.55)	0.675		
Count previous abdominal surgery				
I	1			
II	0.458 (0.08–2.64)	0.383		
III	0.458 (0.03–8.02)	0.593		

OR, odds ratio; CI, confidence interval; BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.

Predictive factors	Univariate OR (95%CI)	p-value	Multivariate OR (95%CI)	p-value
IV	-	-		
ASA class				
Class I	1			
Class II	0.467 (0.14–1.50)	0.201		
Class III	0.378 (0.12–1.19)	0.097		
Class IV	-			
Side				
Left	1			
Right	0.942 (0.44–2.01)	0.879		
Size (mm)	0.899 (0.77–1.04)	0.167		
RENAL score	0.858 (0.68–1.08)	0.198		
RENAL score group				
Min–6	1			
7–9	0.995 (0.45–2.17)	0.991		
10–12	0.404 (0.06–2.67)	0.348		
Length of hospital stay (days)	0.638 (0.50–0.81)	0.000	0.644(0.49–0.83)	0.001
Warm ischemia time (min)	0.992 (0.96–1.02)	0.537		
Cold ischemia time (min)	0.973 (0.94–1.00)	0.067		
Operative time (min)	0.996 (0.99–1.00)	0.196		
Pathologic mass size (cm)	0.938 (0.82–1.06)	0.320		
Pathology				
Renal cell carcinoma	1			
Angiomyolipoma	1.192 (0.52–2.69)	0.673		
Oncocytoma	0.425 (0.06–2.74)	0.370		

OR, odds ratio; CI, confidence interval; BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.

Predictive factors	Univariate OR (95%CI)	p-value	Multivariate OR (95%CI)	p-value
Other	0.798 (0.19–3.28)	0.755		
Renal cell carcinoma				
Clear cell	1			
Papillary	0.533 (0.09–2.95)	0.472		
Chromophobe	0.533 (0.06–4.15)	0.548		
Other	0.267 (0.02–3.17)	0.295		
Intraoperative complications				
No	1		1	
Yes	0.270 (0.11–0.66)	0.004	0.328(0.12–0.89)	0.029
Creatinine				
Preoperative	0.980 (0.64–1.49)	0.926		
2–4 weeks	0.123 (0.03–0.53)	0.005		
eGFR				
Preoperative	1.011 (0.99–1.03)	0.188		
2–4 weeks	1.026 (1.00–1.05)	0.018		
1–3 months	1.028 (1.01–1.05)	0.007		
Operation type				
OPN	1			
LPN	0.837 (0.29–2.34)	0.736		
RAPN	1.685 (0.68–4.12)	0.253		
OR, odds ratio; CI, confidence interval; BMI, body mass index; DM, diabetes mellitus; HT, hypertension; DLP, dyslipidemia; ASA, American Society of Anesthesiologists; PRC, packed red cells; eGFR, estimated glomerular filtration rate; OPN, open partial nephrectomy; LPN, laparoscopic partial nephrectomy; RAPN; robot-assisted partial nephrectomy.				

Discussion

Partial nephrectomy is an appropriate operation for the treatment of renal masses. In the past, OPN was the standard technique. LPN was later developed and is now increasing in use. In Ramathibodi Hospital, RAPN was first performed in 2015. According to the 2017 American Urological Association guideline [8]

and the 12th edition of *Campbell Walsh Wein Urology* [2], partial nephrectomy is recommended for patients with a cT1a renal mass, solitary kidney, bilateral renal tumors, familial RCC, and CKD or proteinuria as well as young patients with multifocal masses or comorbidities that may impact renal function in the future. The most common complications after partial nephrectomy are urine leakage, postoperative bleeding, urinary tract infection, arteriovenous malformations, pseudoaneurysms, and renal abscesses [11].

In the present study, the three groups had similar baseline patient and tumor characteristics except for the RENAL nephrometry score, which was highest in the RAPN group ($p = 0.005$). The EBL was highest in the OPN group ($OPN > RAPN > LPN$, $p = 0.041$). The percentage of patients who required perioperative PRC transfusion ($OPN > LPN > RAPN$, $p = 0.015$) and postoperative PRC transfusion ($p = 0.037$) was lowest in the RAPN group. The operative time was longest in the RAPN group ($RAPN > LPN > OPN$, $p < 0.001$). LOS was not different among the three groups. The rate of positive surgical margins was not significantly different among the three groups but was highest in the LPN group. The rate of collecting system penetration was lowest in the RAPN group. No injury to major vessels or other abdominal organs occurred in any group.

Six patients required conversion to radical nephrectomy. One patient who underwent OPN was converted to open radical nephrectomy because of massive bleeding (EBL of 4300 mL) after unclamping of the renal artery (RENAL score of 8A). The other five patients who underwent RAPN were converted to robotic-assisted radical nephrectomy because of high mass complexity in four patients (RENAL scores of 10P, 10P, 11A, and 10P) and mass involvement of the renal hilum in one patient (RENAL score of 6P).

Two patients underwent conversion to open surgery (LPN to OPN) because of massive adhesion and no progression of LPN in one patient and massive bleeding (EBL of 1500 mL) after unclamping of the renal artery in the other patient.

Three patients developed severe postoperative complications after OPN. The first patient had a grade 3a postoperative arteriovenous fistula (AVF) s/p angiogram requiring embolization. The second patient had grade 4 postoperative respiratory failure requiring mechanical ventilation. The third patient had grade 4b postoperative cardiac arrest with atrial fibrillation requiring rapid ventricular response, respiratory failure with hospital-acquired pneumonia requiring mechanical ventilation, and acute kidney injury requiring hemodialysis.

Three patients developed severe postoperative complications after RAPN. The first patient had a grade 3a postoperative AVF s/p angiogram requiring embolization. The second patient had grade 4a postoperative end-stage renal disease requiring long-term hemodialysis. The third patient had grade 4b postoperative respiratory failure requiring mechanical ventilation and end-stage renal disease requiring long-term renal replacement therapy.

The number of patients with $\geq 90\%$ preservation of the eGFR at the 1-year follow-up was not significantly different among the three groups. The proportion of patients ($n = 116$) who achieved the trifecta outcome

was also similar among the groups ($p = 0.736$). In the multivariate analysis, the factors that affected the trifecta outcome were the LOS and rate of intraoperative complications.

Three patients were readmitted. One patient was given intravenous antibiotics to treat an infected intra-abdominal collection after RAPN, one underwent angiography and embolization of a renal AVF after RAPN, and one underwent angiography and embolization of a renal AVF after OPN.

As in our study, Mehra et al. [16] found that blood loss was lowest in the RAPN group ($OPN > LPN > RAPN$, $p = 0.042$). This can be explained by better visualization of the anatomy and movement control of instruments in RAPN. Similarly, Khalifeh et al. [17] concluded that the rate of a positive surgical margin was lower in RAPN than LPN. This may be due to technical difficulty when performing LPN, especially when the mass is in the upper pole or a posterior location.

Both Zargar et al. [18] and Xia et al. [19] reported that the rate of intraoperative complications was similar in OPN and RAPN. According to Khalifeh et al. [17] and Porpiglia et al. [13], the rate of postoperative complications was lower in RAPN than in LPN and OPN.

As in our study, Zargar et al. [20] found that the postoperative creatinine concentration and eGFR were not different between LPN and RAPN. Yerram et al. [15] found that the proportion of patients with $\geq 90\%$ eGFR preservation at follow-up was not different between OPN and RAPN.

As in our study, Yerram et al. [15] found that achievement of the trifecta outcome (defined as negative surgical margins, no urologic complications, and $\geq 90\%$ eGFR preservation at last follow-up) was not different between OPN and RAPN. This may be explained by the fact that LPN is inferior to both surgical OPN and RAPN because of its more challenging surgical techniques.

Zargar et al. [20] compared 646 LPN with 1185 RAPN procedures and defined the trifecta outcome as negative surgical margins, no perioperative complications, and a warm ischemia time of ≤ 25 min. They found that the factors predicting achievement of the trifecta outcome were the type of surgery (RAPN), tumor size, EBL, and operative time.

As in our study, Mehra et al. [16] found that the operative time was not different among the three groups. In contrast, however, Khalifeh et al. [17] found that the operative time was shorter for RAPN than LPN. This can be explained by the steep learning curve of RAPN and the greater complexity of renal masses (higher RENAL scores) in the RAPN group in our study.

In contrast to our study, Han et al. [21] and Kim et al. [22] concluded that the LOS was significantly shorter for RAPN than OPN. LOS can be affected by many factors, including patient pain control, patient preference, socioeconomic status, and our institute practice.

Khalifeh et al. [17] and Porpiglia et al. [13] concluded that the rate of postoperative complications was lower in RAPN than LPN and OPN. However, we found no statistically significant difference in postoperative complications among our three groups.

Our study has three main limitations. First, it was a retrospective study with a small sample size. Second, the surgeries were performed by eight surgeons, which may have resulted in different outcomes. Third, performance of the eGFR evaluation at 1 year may have been too early to determine the actual long-term renal function outcomes.

Conclusion

There was no statistically significant difference in trifecta outcome achievement among patients who underwent OPN, LPN, and RAPN. LPN and RAPN were associated with lower EBL, a lower transfusion rate, and comparable pathologic outcomes in comparison with OPN. Therefore, both LPN and RAPN are feasible and safe techniques for the treatment of small renal masses. Moreover, LPN and RAPN may be utilized for the treatment of large renal masses in the future.

Declarations

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