Oncological and Functional Outcomes of Laparoscopic Radiofrequency Ablation and Partial Nephrectomy for T1a Renal Masses: A Retrospective Single-center 60 Month Follow-up Cohort Study

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Purpose: It remains unclear whether laparoscopic radiofrequency ablation (RFA) for primary treatment of small renal masses is similar to partial nephrectomy (PN) in terms of long-term oncological and renal function outcomes. We reviewed the long-term outcomes for patients with T1a renal masses treated with either laparoscopic RFA or PN.

Materials and Methods: This retrospective single-center study on 115 patients who were treated by laparoscopic RFA or PN for small (<4 cm) renal masses between January 2005 and October 2014 at Chungnam National University Hospital. Estimated glomerular filtration rate (eGFR) was measured before and 1–2 weeks after surgery and at last follow-up. The laparoscopic RFA and PN groups were compared in terms of clinical characteristics data and change in eGFR after surgery using the Chi-squared test or Student's t-test. Survival data were analyzed using the Kaplan-Meier method and the log-rank test.

Results: Of the 115 patients, 62 and 53 underwent laparoscopic RFA and PN, respectively. Their mean (range) follow-up duration was 60 (30–104) and 68 (30–149) months, respectively ($P = 0.092$). The RFA patients were older ($P = 0.023$) and had smaller tumors ($P = 0.000$). RFA associated with shorter operation and hospitalization times and less perioperative blood loss (all $P<0.001$). The groups did not differ in terms of change in eGFR 1–2 weeks after surgery ($P = 0.252$) or at the last follow-up ($P = 0.395$) or 5 year survival rates ($P = 0.360$).

Conclusion: Laparoscopic RFA for small renal masses was comparable to PN in terms of oncological and functional outcomes and associated with shorter operative and hospitalization times and less perioperative bleeding.

Keywords: kidney neoplasms; partial nephrectomy; radiofrequency ablation

INTRODUCTION

In recent years, the widespread use of contrast-enhanced computed tomography (CT) and magnetic resonance imaging (MRI) has greatly increased the detection of small renal masses (SRMs)[1]. This change has also associated with significant changes in the management of patients with SRMs in the past decade. In particular, SRMs are now routinely treated with partial nephrectomy (PN) rather than radical nephrectomy. This change arose after multiple studies showed that radical nephrectomy associates with higher risks of chronic renal failure, mortality, and hospitalization compared with PN[2–4].

Another recent change in SRM treatment is the increasing use of radiofrequency ablation (RFA), which can be applied via the open, percutaneous, or laparoscopic approaches. This relatively new technique has a significant advantage over PN, namely, it is better at preserving renal function. As a result, the 2009 American Urological Association (AUA) guidelines state that RFA is an optional treatment for SRMs, particularly for patients who have a high operative risk[5]. However, there is some evidence, albeit limited, that suggests that RFA is safe and effective enough to serve as a standard treatment for SRMs. In particular, two retrospective studies show that, for cT1a renal masses, RFA is similar to PN in terms of disease- and cancer-specific survival rates and local control[6,7]. Further research comparing the long follow-up efficacy and safety of laparoscopic RFA and PN for SRMs is very few.

To address this, we conducted a retrospective single-center long follow-up cohort study that directly compared the oncological and renal function outcomes of laparoscopic RFA and PN for cT1a renal masses.

PATIENTS AND METHODS

Patients

After institutional review board approval, the cohort consisted of all consecutive patients with cT1a renal masses who underwent laparoscopic RFA or PN between January 2005 and October 2014. Of the 128 patients, 13 (10%) patients with benign tumors were excluded. All surgeries were performed by a single surgeon. Patients were included if they had undergone a renal mass biopsy, had histologically confirmed renal cell carcinoma, had a small (< 4 cm) solitary tumor, and were followed up for at least 2 years after surgery by contrast imaging studies. Patients with bilateral renal tumors, metastasis at presentation, or hereditary renal tumor were excluded. All patients underwent pre-treatment abdominal CT or MRI and chest radiography.

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Table 1. Preoperative characteristics of the patients undergoing laparoscopic radiofrequency ablation or open partial nephrectomy

Variable	RFA n=62	PN n=53	*P* value[a]
No. (%) male	45 (72.5)	40 (75.5)	0.725
No. (%) female	17 (26.5)	13 (24.5)	
Mean age (range)	58 y (32–84)	53 y (17–77)	0.023
Mean BMI (range), kg/m^2	26 (19–32.6)	24.9 (17.9–31.6)	0.053
No. (%) with diabetes	14 (22.2)	8 (15.1)	0.309
No. (%) with hypertension	30 (48.4)	17 (32.1)	0.076
No. (%) with ASA score:			0.081
1	20 (32.3)	26 (49.1)	
2	32 (51.6)	24 (45.3)	
3	10 (16.1)	3 (0.06)	
Mean preoperative eGFR (range), mL/min	94.2 (35.82–193)	97.5 (30.2–155)	0.499
No. patients with CKD stage:			0.957
1 (eGFR > 90 mL/min)	35	31	
2 (eGFR 90–60 mL/min)	22	17	
3 (eGFR 60–30 mL/min)	5	5	
4 (eGFR 30–15 mL/min)	0	0	
5 (eGFR <15 mL/min)	0	0	

[a] The RFA and PN groups were compared using Student's t-test or Chi-squared test, as appropriate.
ASA=American Society of Anesthesiologists; BMI=body mass index; CKD=chronic kidney disease; eGFR= estimated glomerular filtration rate; RFA=radiofrequency ablation; PN=partial nephrectomy; preop=preoperative.

Surgical techniques

RFA was performed with the laparoscopic approach only. PN was performed via open surgery only. The indication for operation was the presence of an enhancing renal mass on CT or MRI. The choice of surgical method and the approach that was used were based on the location, size, and proximity of the tumor to adjacent organs and patient characteristics such as age and performance status.

The surgical techniques that we used for laparoscopic RFA have been described previously[8]. Thus, a trans-peritoneal or retroperitoneal approach was employed. In particular, when the renal tumor was located in the posterior aspect of the kidney, the retroperitoneal approach was preferred. Renal tumors were identified after removing the perirenal fat and exposing the kidney surface. Laparoscopic ultrasound was performed to identify the endophytic mass and to guide the placement of the RFA needle tip. The maximal ablation time per cycle was 12 minutes. The number of cycles that were applied depended on the size of the tumor and ranged from one to four cycles. Generally, tumors that were <2, 2–3, and >3 cm in diameter were treated with 1–2, 1–4, and 2–4 12 minute cycles, respectively. When more than one cycle was used, the different cycles directed the current at different portions of the tumor. A biopsy was obtained immediately before RFA in all cases.

Open PN was performed using a retroperitoneal approach via a flank or subcostal incision. After exposing the renal tumor and mobilizing the renal hilum, the hilum was cross-clamped and the masses were excised with a safety margin. The renal defect was then repaired.

Follow-up

All patients were discharged when the drain tube was removed and home life was possible. The patients were followed up by periodic physical examinations, chest X-rays, measurement of serum creatinine levels, and CT or MRI. CT/MRI follow-up initially involved scans 1, 3, 6, 12, 18, and 24 months after surgery; thereafter, those were performed every 12 months. The follow-up scan that was performed 1 month after surgery was performed to determine whether residual tumor or enhancing lesions were present after surgery. Recurrence was defined as the detection of a new enhancing lesion or enlargement of the ablation defect after the 1 month follow-up visit. Residual tumors 1 month after surgery were included in the study, but no recurrences were detected in the 1 month follow-up scan. There was no patient lost to follow-up.

Statistical techniques

The RFA and PN groups were compared in terms of clinical characteristics data using the Chi-squared test or Student's *t*-test, as appropriate. The RFA and PN groups were compared in terms of survival using the Kaplan-Meier method and the log-rank test. A p value less than 0.05 was considered to indicate a statistically significant difference between the groups. All statistical analyses were performed using IBM SPSS Statistics ver. 20.0 (IBM Co., Armonk, NY, USA).

RESULTS

Preoperative characteristics of the patients

During the ~9 year study period, 115 patients with T1a renal tumors underwent laparoscopic RFA (n = 62) or PN (n = 53). Their clinical and functional features are summarized in **Table 1**. The RFA patients were significantly older at treatment (58 years) than the PN patients (53 years, $P = 0.023$), but the two groups did not differ in terms of gender ($P = 0.725$), body mass index ($P = 0.053$), diabetes ($P = 0.309$), hypertension ($P = 0.076$), American Society of Anesthesiologists score ($P = 0.081$), preoperative estimated glomerular filtration rate (eGFR) ($P = 0.499$), or chronic kidney disease (CKD) stage ($P = 0.957$).

Tumor characteristics

The tumor characteristics of the RFA and PN patients are shown in **Table 2**. The RFA patients had significantly smaller tumors (mean size, 2.14 cm) than the PN group (2.75 cm, $P = 0.00$). However, the two groups did not differ significantly in terms of frequency of the

Table 2. Tumor characteristics

Variable	RFA n=62	PN n=53	*p* value[a]
Mean (range) tumor size, cm	2.14 (0.8–3.6)	2.75 (1.3–4)	0.00
No. (%) on the right side	38 (61.3)	28 (52.8)	0.360
No. (%) on the left side	24 (38.7)	23 (47.2)	
Pole location			0.153
No. (%) on upper pole	10 (16.1)	16 (30.2)	
No. (%) on middle pole	23 (37.1)	17 (32.1)	
No. (%) on lower pole	29 (46.8)	20 (37.7)	
Tumor depth			0.274
No. (%) exophytic	16 (25.8)	12 (22.7)	
No. (%) mesophytic	38 (61.3)	28 (52.8)	
No. (%) endophytic	8 (12.9)	13 (24.5)	
Histological subtype			0.294
No. (%) clear cell	49 (78.9)	37 (69.8)	
No. (%) papillary	3 (4.8)	5 (9.4)	
No. (%) chromophobe	6 (9.7)	8 (15.1)	
No. (%) oncocytoma	2 (3.3)	0 (0)	
No. (%) cystic renal cell	0 (0)	2 (3.8)	
No. (%) unclassified	2 (3.3)	1 (1.9)	
No. surgical failures			
Incomplete	0	0	
Recurrence	0	0	

[a] The RFA and PN groups were compared using Student's t-test or Chi-squared test, as appropriate.

PN = partial nephrectomy; RFA = radiofrequency ablation.

tumor on the right or left side (*P* = 0.360), tumor pole location (*P* = 0.153), tumor depth (*P* = 0.274), or histological subtype (*P* = 0.294). One month after surgery, remnant tumor or recurrence was not detected in any of the patients.

Perioperative and postoperative characteristics

The perioperative and postoperative outcomes of RFA and PN are shown in Table 3. The RFA and PN groups were followed up for similar average durations (60 vs. 68 months, *P* = 0.092). On average, laparoscopic RFA took only 110 minutes as compared with 173 minutes for PN ($P < 0.001$). RFA also associated with a significantly shorter hospital stay (8, range 5–19, days) than PN (13, range 9–28, days, $P < 0.001$). Moreover, RFA associated with a lower mean preoperative to nadir change in hematocrit (4.5, range -0.2–12.8) than PN (8.9, -2–23.3, $P < 0.001$).

Of 115 patients undergoing RFA or PN, 3 (2.6%) patients had major complications. One patient who underwent PN was recovered after coil embolization due to pseudoaneurysm with bleeding of renal artery after surgery. Two of the patients who underwent RFA had CKD aggravation and ureteral stricture, respectively. The case with ureteral stricture was the third laparoscopic RFA in our center and then nephrectomy was performed due to renal shrinkage at 3 months later.

Table 4 reports the number of ablation cycles used per patient in the laparoscopic RFA group. The number of ablation cycles that were applied depended on the size of the tumor, the laparoscopic ultra-sonographic findings, and the judgement of the surgeon. The 23 tumors that were less than 2 cm in diameter were treated with one cycle in 14 patients (61%) and two cycles in nine patients (39%). The 29 tumors that were 2–3 cm in diameter were treated with one cycle in three patients (10.4%), two cycles in 18 patients (62.1%), three cycles in seven patients (24.1%), and four cycles in one patient (3.4%). Of the 10 patients with tumors that were 3–4

Table 3. Perioperative and postoperative characteristics

Variable[a]	RFA n=62	PN n=53	*p* value[b]
Operation time, min	110 (40–240)	173 (80–300)	0.00
Hospital stay, days	8 (5–19)	13 (9–28)	0.00
Change in preop to nadir Hct	4.5 (-0.2–12.8)	8.9 (-0.2–23.3)	0.00
Follow-up, months	60 (30–104)	68 (30–149)	0.092
Preop eGFR, mL/min	94.2 (30.2–155)	97.5 (35.8–193)	0.499
eGFR at 1–2 wks FU, mL/min	96 (23.8–142)	95.2 (48–208)	0.867
eGFR at last FU, mL/min	84.3 (18.4–138)	91 (41.9–133.7)	0.092
Change in eGFRc, mL/min			
follow-up at 1–2 weeks	-1.81 (-41.2–34.2)	2.3 (-45.09–63.7)	0.252
At last follow-up (range)	9.85 (-26.7–47.9)	6.53 (-62.8–90.3)	0.395

[a] All data are shown as mean (range).
b The RFA and PN groups were compared using Student's *t*-test or Chi-squared test, as appropriate.
c Mean change relative to the eGFR before surgery.
eGFR = estimated glomerular filtration rate; FU, follow-up; Hct = hematocrit; preop=preoperative; PN = partial nephrectomy; RFA=laparoscopic radiofrequency ablation.

Table 4. Number of ablation cycles used for different tumor sizes in radiofrequency ablation

No. of ablation cyclesa	Tumor < 2 cm n = 23	Tumor 2–3 cm n = 29	Tumor 3–4 cm n = 10
One cycle	14 (61)	3 (10.4)	0
Two cycles	9 (39)	18 (62.1)	1 (10)
Three cycles	0	7 (24.1)	4 (40)
Four cycles	0	1 (3.4)	5 (50)

[a] The data are shown as number (%).

cm in diameter, one (10%) underwent two cycles, four (40%) underwent three cycles, and five (50%) underwent four cycles.

Changes in renal function

The renal function of the RFA and PN groups after surgery is summarized in Table 3. The RFA and PN groups had similar mean preoperative eGFR values (94.2 vs. 97.5 mL/min, $P = 0.499$). They also had similar mean eGFR values 1–2 weeks after surgery (96.2 vs. 95.2 mL/min, $P = 0.867$) and at the last follow-up visit (84.3 vs. 91 mL/min, $P = 0.092$). Moreover, the RFA and PN patients did not differ in terms of the change in mean eGFR (relative to preoperative values) 1–2 weeks after surgery (-1.81 vs. 2.3, $P = 0.252$) or at the last follow-up (9.85 vs. 6.53, $P = 0.395$).

Oncological outcomes

The oncological outcomes of the RFA and PN groups during follow-up (starting 1 month after surgery) are shown in Table 5. None of the patients had residual disease (i.e., an enhancing lesion at the original site of the tumor) or developed local recurrence or new metachronous tumors. Moreover, none died from the disease. Thus, the 5 year recurrence-free, metastasis-free, cancer-specific, and disease-specific survival rates of the RFA and PN groups were all 100%. During follow-up, two of the 62 patients in the RFA group died. One developed CKD progression and pneumonia 44 months after the initial RFA. However, the eGFR of the patient was 30.2 mL/min, representing a drop in renal function, The other patient died of hepatocellular carcinoma 73 months after the initial RFA. Thus, the 5 year overall survival rates of the laparoscopic RFA and PN groups were 98.4% and 100%, respectively ($P = 0.360$).

Long-term outcomes of patient with a follow-up period of more than 5 years

Of the 115 patients, 61 (53%) patients were followed-up for more than 5 years. The number of RFA and PN patients was 30 and 31, respectively. The RFA and PN subgroups were followed up for similar average durations (77.5 vs. 86.6 months, $P = 0.084$). The long-term outcomes of RFA and PN subgroups after surgery are shown in Table 6. The RFA and PN subgroups did not differ in term of the change in mean eGFR 1-2 weeks after surgery (1.9 vs 2.9, $P = 0.825$) or at the last follow-up (12.0 vs. 4.1, $P = 0.201$). In addition, no local recurrence or new metachronous tumor were seen in patients who underwent RFA and PN during follow-up for more than 5 years. Thus, the 5 year recurrence-free, metastasis-free, cancer-specific, disease-specific, and overall survival rates of the RFA and PN groups were all 100%.

DISCUSSION

PN is currently the treatment of choice for cT1 renal masses, and RFA is considered to be an optional treatment for patients with high operative risk[5,9]. This preference for PN is likely to reflect the relative lack of data showing the long-term oncological outcomes of RFA. However, several recent studies showed that RFA and PN for cT1a renal masses have comparable oncological outcomes[6,10].

RFA can be performed via the open, percutaneous, and laparoscopic approaches[11]. There is little research on RFA with open approach as it is seldom performed. Most studies on RFA are on ablation performed via the percutaneous approach[12–14]. Thus, Hegarty et al. showed that percutaneous RFA on 82 renal masses associated with a recurrence-free survival rate of 88.9% after a median follow-up duration of 12 months[12]. Similarly, Zagoria et al. reported that, when 125 patients underwent percutaneous RFA, the recurrence-free survival rate after a mean follow-up duration of 13.8 months was 87%[13]. Moreover, Levinson et al. reported that the recurrence-free survival rate of 31 renal masses was 90.3% after a mean follow-up duration of 61.8 months[14].

By contrast, very few studies have assessed the oncological efficacy of RFA via the laparoscopic approach. In 2003, Jacomides et al. were the first to document

Table 5. Oncological outcomes

Variable	RFA n=62	PN n=53	*p* value
No. with residual disease	0	0	
No. with local recurrence	0	0	
No. with new metachronous tumor	0	0	
No. disease-specific deaths	0	0	
No. deaths (overall)	2	0	0.163
5 year recurrence-free survival, %	100	100	
5 year metastasis-free survival, %	100	100	
5 year cancer-specific survival, %	100	100	
5 year disease-free survival, %	100	100	
5 year overall survival, %	98.4	100	0.360

PN=partial nephrectomy; RFA=laparoscopic radiofrequency ablation.

Table 6. Long-term outcomes of patients with a follow-up period of more than 5 years

Variable	RFA	PN	*p* value
Number of patient	30	31	
Follow-up, months	77.5 (62-104)	86.6 (60-149)	0.084
Change in eGFR, mL/min			
follow-up at 1–2 weeks	1.9 (-27.6-34.2)	2.9 (-45.1-63.7)	0.825
At last follow-up (range)	12.0 (-26.7-47.9)	4.1 (-62.8-41.9)	0.201
No. with residual disease			
No. with local recurrence	0	0	
No. with new metachronous tumor	0	0	
No. disease-specific deaths	0	0	
No. deaths (overall)	0	0	
5 year recurrence-free survival, %	1	0	0.290
5 year metastasis-free survival, %	100	100	
5 year cancer-specific survival, %	100	100	
5 year disease-free survival, %	100	100	
5 year overall survival, %	100	100	

PN=partial nephrectomy; RFA=laparoscopic radiofrequency ablation.

their initial experiences with laparoscopic RFA in 13 patients[15]. A few years later, Park et al. presented the intermediate follow-up outcomes of laparoscopic RFA in 39 patients. The operative success rate (i.e., full ablation) and the recurrence-free survival rate were 96.4% and 94.5%, respectively[16]. Finally, Ji et al. reported in 2011 that 106 patients who underwent laparoscopic RFA had a local tumor control rate of 98.1% after a maximal follow-up duration of 48 months[10].

The laparoscopic approach to RFA has the advantage over the percutaneous approach in that it allows more mobilization of the kidney and the renal tumors and allows observation of the thermal changes in the tumor during RFA: these advantages prevent damage to the muscles and perirenal organs. In addition, the laparoscopic approach allows the surgeon to perform additional cycles of ablation or conduct laparoscopic ultrasonography to determine the condition of the tumor when the surgeon suspects that the ablation is incomplete.

This study showed that laparoscopic RFA for renal masses was effective in terms of both oncological and renal function outcomes after a mean follow-up duration of 60 months. First, none of the 62 patients who were treated with laparoscopic RFA and then followed up for at least 30 months exhibited incomplete ablation or local recurrence. Second, the cancer-specific and disease-free survival rates of the RFA patients were both 100%, while their 5 year overall survival rate was 98.4% (61/62). These observations matched those made in the PN group. Third, laparoscopic RFA and PN did not differ significantly in terms of change in renal function after surgery relative to baseline regardless of whether eGFR was tested shortly after surgery or at the last follow-up visit. Finally, there was no difference between RFA and PN groups when subgroup analysis was performed on patients with a follow - up period of 5 years or more.

The current study has several limitations. First, it is a retrospective study and as such may be subject to selection and information bias. Second, because RFA equipment can vary widely, the surgical outcomes of our hospital cannot be generalized to those of other centers that perform laparoscopic RFA. Finally, the sample size of the study was relatively small, which may have affected our ability to detect significant differences between laparoscopic RNA and open PN in terms of oncological and functional outcomes. Nevertheless, despite these limitations, this study adds to the limited existing data regarding the long-term effects of laparoscopic RFA for SRMs. These data suggest that broader use of laparoscopic RFA for SRMs may be justified. Further RCT or studies are needed to verify this.

CONCLUSIONS

This retrospective long-term single-center cohort study showed that laparoscopic RFA for T1a renal masses had comparable oncological and renal function outcomes to PN. In addition, laparoscopic RFA associated with less perioperative bleeding and shorter operative times and hospital stays than PN. Prospective randomized multicenter trials with more patients and long-term follow-up durations that compare laparoscopic RFA and PN in terms of their safety and oncological efficacy in the treatment of T1 renal tumors are warranted.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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