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ORIGINAL ARTICLE

Radiofrequency ablation versus partial nephrectomy for treatment of renal masses: A systematic review and meta-analysis

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Abstract Our study was to collect the data available in the literature on radiofrequency ablation (RFA) and partial nephrectomy (PN) and conduct a cumulative analysis on perioperative outcomes, renal function outcomes, and survival to evaluate the overall safety and efficacy of RFA versus PN for small renal cell cancer (SRCC). A literature search was carried out using various electronic databases. Data including age, tumor size, comorbid disease, operation duration, hospital stay, pre- and postoperative estimated glomerular filtration rate (eGFR), major and minor complications, and local tumor recurrence and metastasis were collected for meta-analysis. Sixteen studies were included for this meta-analysis. The age of patients treated with RFA was significantly older than that of patients treated with PN [weighted mean difference (WMD) = 5.07 years]. There were more patients with cardiovascular disease in RFA group as compared with PN group [odds ratio (OR) = 4.24] before treatment. RFA was associated with a shorter length of hospital stay compared with PN (WMD = −2.02 days). No significant difference was found in major and minor complications between the two groups (major: OR = 0.74; minor: OR = 0.45). Preoperative eGFR and eGFR decline in RFA patients was significantly lower than that in PN patients (WMD = −7.27 and −4.82, respectively), whereas there was no significant difference in postoperative eGFR (WMD = −1.18). The local tumor recurrence rate in RFA group was higher than that in PN group (OR = 1.81). However, the distant

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metastasis rate was no statistical difference between the two groups (OR = 1.63). RFA is a suitable therapeutic option for older patients and those at high risk for SRCC because of a low risk of operation and better preservation of renal function.

Introduction

There were 65,150 new cases of, and 13,680 deaths from, kidney cancer based the 2013 cancer incidence statistics estimated in the United States; meanwhile, kidney cancer was the second leading cause of urinary cancer-related death [1]. It is well known that renal cell cancer (RCC) is the most common form of kidney cancer. The widespread use of routine abdominal imaging technologies including ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) in recent years has made it possible to diagnose asymptomatic small renal cell cancer (SRCC) earlier [2], and > 50% of SRCC can be diagnosed at Stage T1a [3].

According to the 2010 Update European Association of Urology (EAU) Guidelines [4], surgery is the only curative treatment for RCC. For T1 SRCC, surgical treatment modalities have evolved from radical nephrectomy to nephron-sparing surgery (NSS). The EAU Guidelines on Renal Cell Carcinoma recommend NSS as the treatment of choice for RCC, though open partial nephrectomy (PN) remains the gold standard [4]. Generally speaking, PN requires a period of overall renal ischemia, and a prolonged duration (> 30 minutes) of ischemia would subject the kidneys to possible ischemic insults, resulting in hemorrhage and decreasing renal function [5]. However, it is difficult to perform PN in cancer patients with comorbid disease [6]. These adverse factors of PN have encouraged investigators to develop a new, safe, and effective surgical option instead of PN.

Radiofrequency ablation (RFA) has been increasingly accepted as a potentially promising nephron-sparing, minimally invasive therapeutic option for patients with small localized renal masses. In addition, RFA as a primary or adjuvant treatment modality has been widely used in solid tumors such as hepatocellular carcinoma, lung cancer, breast cancer, and RCC [7]. In 1997, Zlotta et al [8] reported the first clinical use of renal RFA for the treatment of localized renal masses. RFA destroys the kidney tumor mass *in situ* by using a high-frequency alternating current to heat a volume of tissue [9]. RFA, as an outpatient procedure, can be carried out by open, laparoscopic, and percutaneous approaches. In addition, RFA avoids ischemic insults and incises the renal parenchyma compared with PN.

However, it is still a topic of controversy regarding the superiority of RFA versus PN for management of SRCC masses. Based on the literature currently available, thermal ablation has several advantages, including preservation of renal function, decreased perioperative mortality, faster postoperative recovery, and reduced postoperation frequency of cardiovascular events [10]. Because of the lack of randomized controlled trials, all studies that we searched were retrospective, nonrandomized, observational studies. Therefore, the evidence in the current literature is low and whether RFA can replace PN for special patient needs to be studied further. The main aim of this meta-analysis is to collect the existing literature that makes comparisons between RFA and PN and performs cumulative analyses on perioperative, renal function, and oncological outcomes in an attempt to evaluate the overall safety and efficacy of RFA versus PN for SRCC.

Methods

Literature search

A systematic search was carried out using electronic databases, including PubMed, Google Scholar, Embase, Web of Science, and the Cochrane library. The search was performed until August 2015, and only articles published in the English language were considered. A hand-search of the reference lists of relevant articles was also conducted. The combination of the following words was used "partial nephrectomy", "PN", "radiofrequency ablation", "RFA". All eligible studies were included for further screening.

Study selection

Inclusion and exclusion criteria of studies were identified before the literature search. All eligible studies were included if they met the following criteria: (1) studies comparing RFA with PN with respect to perioperative outcomes and renal function outcomes and survival; and (2) patients with renal masses in the normal kidney or solitary kidney as defined by ultrasonography, CT, or MRI. Patients with comorbidities who underwent RFA were also included. Exclusion criteria were as follows: studies without conducting comparisons between RFA and PN; and patients with distant metastasis, vascular invasion, hereditary renal cancer syndromes, and bilateral or metachronous tumors who were followed up for < 1 year. Study selection was independently performed by two reviewers and disagreements in this procedure were resolved by consensus.

Quality assessment

The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analysis was used to evaluate the methodological quality of the enrolled studies. The NOS known as a "star system" includes three broad perspectives: study group selection

(4 items), group comparability (2 items), and outcome ascertainment (3 items) [11]. The score of NOS ranges between one and nine stars. Two reviewers independently carried out the quality assessment and had discussions about any disagreement.

Data extraction

Two reviewers independently carried out data extraction by searching the full texts of included studies. The extracted data were authors, journal and publication year, number of patients, age, tumor size, comorbid disease, length of hospital stay, pre- and postoperative estimated glomerular filtration rate (eGFR), major and minor complications, tumor recurrence and metastasis, overall survival (OS), local recurrence-free survival (RFS), cancer-specific survival (CSS), disease-free survival (DFS), and costs.

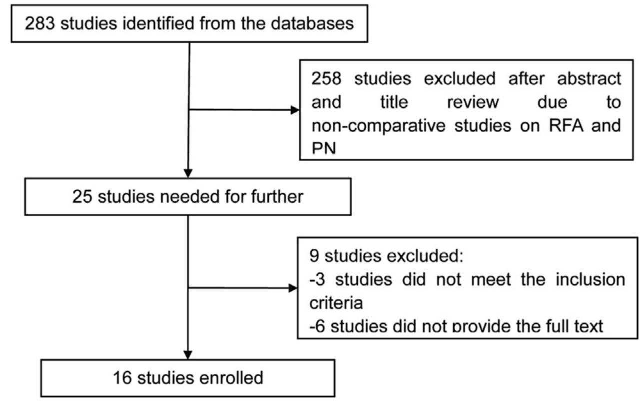


Figure 1. Flowchart showing screening studies for the meta-analysis.

Table 1 Baseline characteristics of included studies.

Study	Treatment	No. of patients	Age (year)	Tumor size (cm)	Baseline eGFG (ml/min/1.73 m^2)	Co-morbid disease			Publication type
						DM (%)	Hypertension (%)	Cardiovascular disease (%)	
Thompson 2015 [28]	PN	1057	60.1	2.5	—	—	—	—	Non-RCT
	RFA	180	70.1	2.1	—	—	—	—	
Chang 2015 [29]	PN	134	53.9	4.0	105.7	—	—	—	Non-RCT
	RFA	134	56.6	3.6	97.2	—	—	—	
Youn 2013 [14]	PN	14	53.9	2.4	72.91	—	—	—	Non-RCT
	RFA	41	59.2	2.3	73.75	—	—	—	
Psutka 2013 [15]	PN	194	57.4	2.6	—	—	—	—	Non-RCT
	RFA	186	71.4	3.1	—	—	—	—	
Pilkington 2013 [16]	PN	12	64.4	5.2	63.0	—	—	—	Non-RCT
	RFA	18	71.2	5.2	59.6	—	—	—	
Faddegon 2013 [17]	PN	205	54.3	3.1	80.7	18.0	50.7	—	Non-RCT
	RFA	142	61.3	2.3	75.0	18.3	42.2	—	
Sung 2012 [18]	PN	110	53.4	2.2	89.7	9.1	20.9	0.9	Non-RCT
	RFA	40	59.8	2.4	75.2	12.5	47.5	10.0	
Olweny 2012 [19]	PN	37	54.8	2.5	—	—	—	—	Non-RCT
	RFA	37	63.8	2.1	—	—	—	—	
Takaki 2010 [20]	PN	10	64.0	1.9	68.6	20.0		30.0	Non-RCT
	RFA	51	69.4	2.4	49.2	19.6		68.6	
Raman 2010 [21]	PN	42	59.6	3.5	55.9	—	—	—	Non-RCT
	RFA	47	65.9	2.7	46.5	—	—	—	
Iwamoto 2010 [22]	PN	23	64.1	2.2	57.3	13.0	4.34	8.69	Non-RCT
	RFA	30	68.6	2.2	59.9	10.0	20.0	13.3	
Turna 2009 [23]	PN	36	60.3	3.7	65.0	—	—	—	Non-RCT
	RFA	29	60.7	2.6	53.2	—	—	—	
Bird 2009 [24]	PN	33	57.8	2.8	82.3	—	—	—	Non-RCT
	RFA	36	75.2	3.1	62.8	—	—	—	
Lucas 2008 [25]	PN	85	56.2	2.6	70.9	14.1	44.7	—	Non-RCT
	RFA	86	61.5	2.3	73.4	20.9	46.5	—	
Stern 2007 [26]	PN	37	56.4	2.4	—	—	—	—	Non-RCT
	RFA	40	60.5	2.4	—	—	—	—	
Bensalah 2007 [27]	PN	50	56.5	2.6	—	—	—	—	Non-RCT
	RFA	38	62.0	2.3	—	—	—	—	

Data presented as mean or rate. eGFR = estimated glomerular filtration rate; DM = diabetes mellitus; RCT = randomized controlled trial.

Statistical analysis

A meta-analysis was performed to evaluate the overall efficacy of RFA and PN. Tests for homogeneity were performed by the Cochrane Inconsistency (I^2) and Chi-square tests. A value of $p < 0.10$ shows heterogeneity of enrolled studies, whereas $I^2 <$ 50% shows acceptable heterogeneity. Dichotomous variables and continuous variables were pooled by odds ratio (OR) and weighted mean difference (WMD), respectively. The fixed-effects model (Mantel-Haenszel method) [12] was used to calculate pooled estimates for homogeneous studies, and the random-effects model (DerSimonian-Laird method) [13] was applied for heterogeneous studies. The pooled effects were measured by means of Z-test, and $p \leq 0.05$ was considered statistically significant. We used Review Manager (RevMan 5.2, Cochrane Collaboration, Oxford, England) to complete data analysis.

Results

Description of studies

After a systemic literature search of PubMed, Google Scholar, Embase, Web of Science, and the Cochrane library, a total of 283 relevant studies were identified for further screening. Finally, 16 studies [14–29] were included. The process of identification and the eligibility of the included studies are shown in Figure 1. Table 1 shows the baseline characteristics of the enrolled studies. The result of quality assessment of the included studies by NOS is represented in Table 2. Nine studies that were considered as high quality won a score of nine stars and the remaining seven studies were scored eight stars on account of insufficient follow-up.

The patients treated with RFA were significantly older than that of patients treated with PN [WMD = 5.07 years, 95% confidence interval (CI): 3.50–6.64, $p < 0.00001$; Figure 2). The tumor size was similar between the two groups (WMD = −0.20, 95% CI: −0.41–0.02, $p = 0.07$; Figure 2). In addition, more patients in the RFA group had cardiovascular disease than those in the PN group before treatment (OR = 4.24, 95% CI: 1.57–11.47, $p = 0.004$), whereas there was no statistically significant difference in comorbid diseases including diabetes mellitus (DM) and hypertension between the two groups (DM: OR = 1.27, 95% CI: 0.86–1.87, $p = 0.24$; hypertension: OR = 1.52, 95% CI: 0.67–3.43, $p = 0.32$; Figure 3).

Perioperative outcomes

According to statistical analysis, RFA was associated with a shorter length of hospital stay compared with PN (WMD = −2.02 days, 95% CI: −2.82-−1.22, $p < 0.00001$; Figure 4). Eight studies [14,18,20,23,24,26,27,29] reported postoperative complications for both RFA and PN. Of them, seven studies [14,18,23,24,26,27,29] provided data regarding major complications (Grades III-V of Clavien-Dindo classification [30]), and five studies [20,23,24,26,27] provided data on minor complications

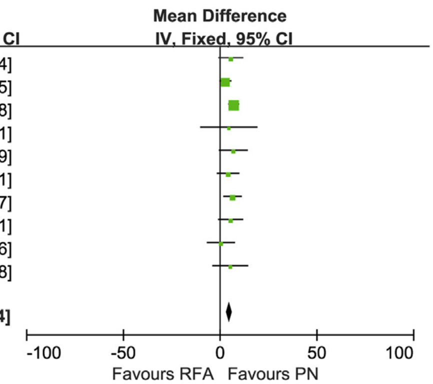
Table 2 The Newcastle-Ottawa scale for quality assessment of included studies.

Study	Selection				Comparability	Outcomes			Total score
	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Outcome of interest was not present at start of study	based on the design or analysis	Assessment of outcome	Follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	
Thompson 2015 [28]	1	1	1	1	1	1	1	1	9
Chang 2015 [29]	1	1	1	1	1	1	1	1	9
Youn 2013 [14]	1	1	1	1	1	1	1	1	9
Psutka 2013 [15]	1	1	1	1	1	1	1	1	9
Pilkington 2013 [16]	1	1	1	1	1	1	0	1	8
Faddegon 2013 [17]	1	1	1	1	1	1	1	1	9
Sung 2012 [18]	1	1	1	1	1	1	1	1	9
Olweny 2012 [19]	1	1	1	1	1	1	1	1	9
Takaki 2010 [20]	1	1	1	1	1	1	0	1	8
Raman 2010 [21]	1	1	1	1	1	1	0	1	8
Iwamoto 2010 [22]	1	1	1	1	1	1	0	1	8
Turna 2009 [23]	1	1	1	1	1	1	1	1	9
Bird 2009 [24]	1	1	1	1	1	1	0	1	8
Lucas 2008 [25]	1	1	1	1	1	1	1	1	9
Stern 2007 [26]	1	1	1	1	1	1	0	1	8
Bensalah 2007 [27]	1	1	1	1	1	1	0	1	8

A

Study or Subgroup	RFA Mean	RFA SD	RFA Total	PN Mean	PN SD	PN Total	Weight	Mean Difference IV, Fixed, 95% CI
Bensalah 2007	62	17.5	38	56.5	11.7	50	6.0%	5.50 [-0.94, 11.94]
Chang 2015	56.6	14.6	134	53.9	11.5	134	25.0%	2.70 [-0.45, 5.85]
Faddegon 2013	61.3	13.2	142	54.3	12.7	205	31.9%	7.00 [4.22, 9.78]
Iwamoto 2010	68.6	28.66	30	64.1	26.13	23	1.1%	4.50 [-10.31, 19.31]
Pilkington 2013	71.2	8.03	18	64.4	11.5	12	4.4%	6.80 [-0.69, 14.29]
Stern 2007	60.5	13.5	40	56.4	12.5	37	7.3%	4.10 [-1.71, 9.91]
Sung 2012	59.8	13.6	40	53.4	11.9	110	10.9%	6.40 [1.63, 11.17]
Takaki 2010	69.4	9.6	51	64	9.6	10	5.8%	5.40 [-1.11, 11.91]
Turna 2009	60.7	14.3	29	60.3	15.5	36	4.7%	0.40 [-6.86, 7.66]
Youn 2013	59.15	12.26	41	53.92	16.14	14	2.9%	5.23 [-4.02, 14.48]
Total (95% CI)			**563**			**631**	**100.0%**	**5.07 [3.50, 6.64]**

Heterogeneity: Chi² = 6.26, df = 9 (P = 0.71); I² = 0%
Test for overall effect: Z = 6.32 (P < 0.00001)



B

Study or Subgroup	RFA Mean	RFA SD	RFA Total	PN Mean	PN SD	PN Total	Weight	Mean Difference IV, Random, 95% CI
Bensalah 2007	2.3	0.7	38	2.6	0.9	50	10.7%	-0.30 [-0.63, 0.03]
Chang 2015	3.6	1.5	134	4	1.2	134	10.8%	-0.40 [-0.73, -0.07]
Faddegon 2013	2.31	0.78	142	3.1	2.8	205	9.5%	-0.79 [-1.19, -0.39]
Iwamoto 2010	2.2	0.4	30	2.2	0.42	23	12.6%	0.00 [-0.22, 0.22]
Lucas 2008	2.34	0.79	86	2.63	0.83	85	12.2%	-0.29 [-0.53, -0.05]
Pilkington 2013	5.17	1.01	18	5.2	1.47	12	3.7%	-0.03 [-0.98, 0.92]
Stern 2007	2.41	0.7	40	2.43	0.8	37	10.6%	-0.02 [-0.36, 0.32]
Sung 2012	2.44	1.27	40	2.23	1.02	110	9.0%	0.21 [-0.23, 0.65]
Takaki 2010	2.4	0.7	51	1.9	0.7	10	8.4%	0.50 [0.03, 0.97]
Turna 2009	2.6	1	29	3.7	1.9	36	5.4%	-1.10 [-1.82, -0.38]
Youn 2013	2.3	1.27	41	2.4	0.79	14	7.1%	-0.10 [-0.67, 0.47]
Total (95% CI)			**649**			**716**	**100.0%**	**-0.20 [-0.41, 0.02]**

Heterogeneity: Tau² = 0.08; Chi² = 32.54, df = 10 (P = 0.0003); I² = 69%
Test for overall effect: Z = 1.81 (P = 0.07)

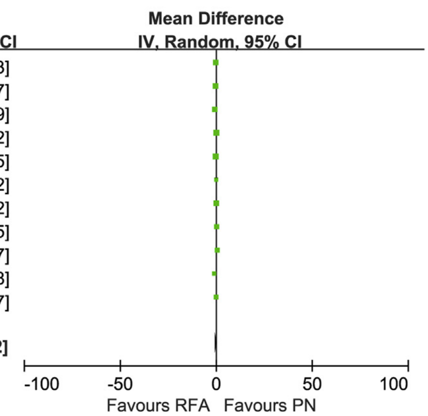


Figure 2. Pooled estimates of (A) age and (B) tumor size.

(Grades I and II). No significant difference was found in major and minor complications between the two groups (major: OR = 0.74, 95% CI: 0.35–1.55, $p = 0.42$; minor: OR = 0.45, 95% CI: 0.11–1.88, $p = 0.27$; Figure 4). With its various surgical approaches, the cost comparison of NSS techniques for renal tumors is shown in the Discussion section.

Renal function outcomes

Eleven studies [14,16–18,20–25,29] reported renal function outcomes, and six studies [16,17,18,22,23,29] provided data available for meta-analysis. Preoperative eGFR in patients who were treated with RFA was significantly lower than that in patients who underwent PN (WMD = −7.27, 95% CI: −11.99-−2.55, $p = 0.003$; Figure 5). However, there was no significant difference in postoperative eGFR between the two groups (WMD = −1.18, 95% CI: −7.13-4.77, $p = 0.70$; Figure 5). The mean eGFR decline in the RFA group was significantly lower than that in the PN group (WMD = −4.82, 95% CI: −9.33-−0.31, $p = 0.04$; Figure 5).

Survival

Eleven studies [14,15,19–21,23,25–29] reported oncological outcomes. Two studies [14,20] showed none of patients with local tumor recurrence between the two groups, and six studies [14,15,21,25–27] reported no distant metastases between the two groups. The local tumor recurrence rate in the RFA group was higher than that in the PN group (OR = 1.81, 95% CI: 1.14–2.88, $p = 0.01$; Figure 6). However, the distant metastasis rate was similar between the two groups (OR = 1.63, 95% CI: 0.74–3.58, $p = 0.22$; Figure 6). Given the differences in the follow-up duration, there was no consensus on the duration of OS, local RFS, DF, and CSS among the studies included, and therefore these variables were not considered in this meta-analysis.

Discussion

With advances in surgical technologies, NSS has been increasingly accepted in the management of RCC, thus providing new opportunities for both the surgeon and the patient to choose a more appropriate treatment. PN as a standard treatment option is extremely effective in the surgical treatment of SRCC. However, RFA, a less invasive and nephron-sparing technique, has been rapidly adopted in patients with SRCC. Potential conditions of patient selection for RFA can be divided into two categories: (1) patients who are considered poor surgical candidates because of inadequate renal function and/or comorbid disease, such as a solitary functional or anatomic kidney, coronary artery disease, cardiomyopathy, or chronic obstructive pulmonary

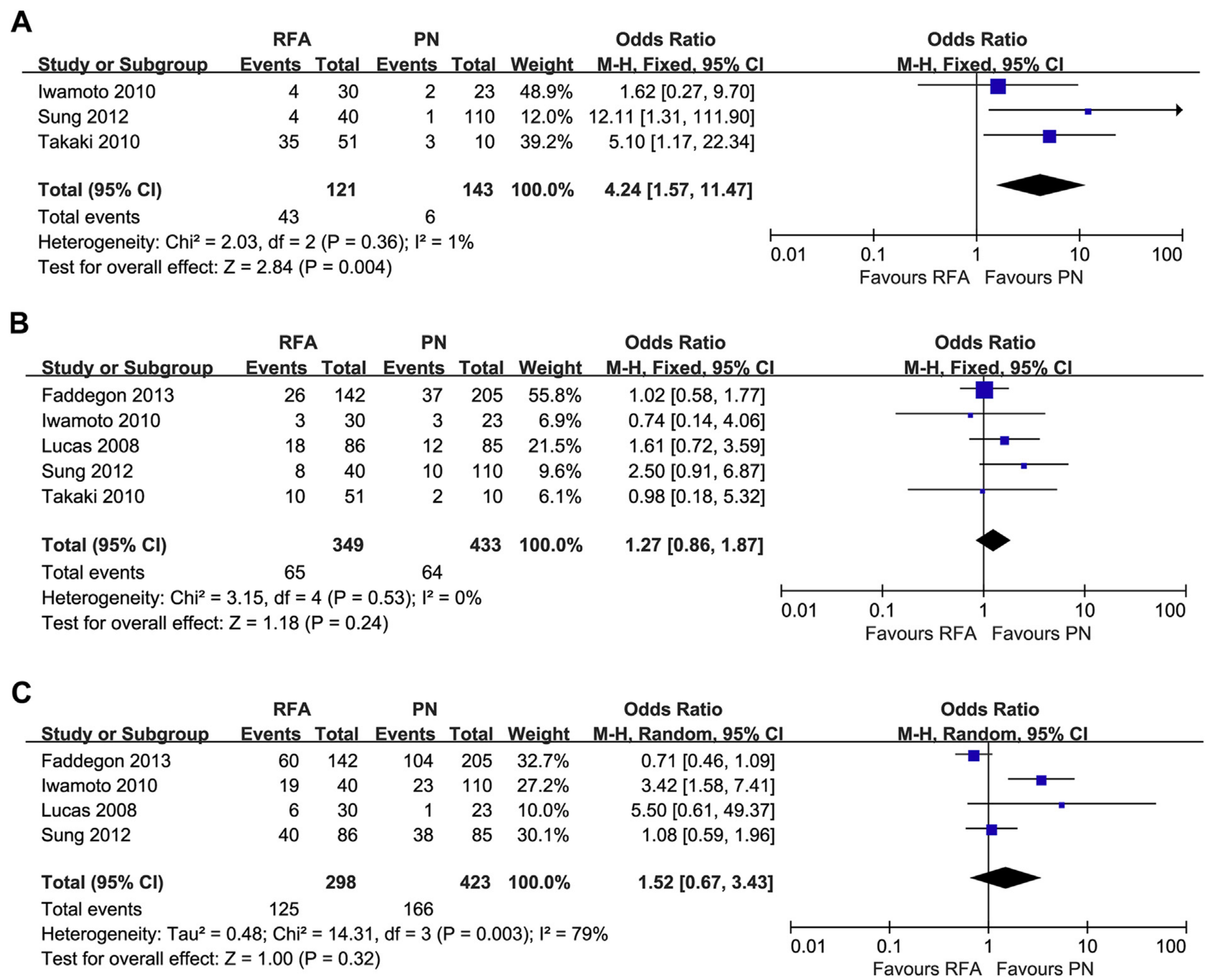


Figure 3. Pooled estimates of (A) cardiovascular disease, (B) diabetes mellitus, and (C) hypertension.

disease, and (2) patients with a high risk of RCC recurrence as genetic syndromes [31].

For choosing a suitable operation method, perioperative outcomes, renal function outcomes, and oncological outcomes are important points in preoperative evaluation. However, only a few studies in the literature compared RFA and PN. The result of the current meta-analysis showed that RFA is safe and feasible for the management of SRCC in high-risk patients.

The AUA guidelines [32] recommend thermal ablation as the treatment of choice for patients with comorbid diseases including DM, hypertension, chronic renal failure, cerebrovascular disease, and cardiovascular disease. In other words, RFA is more suitable for patients who have high surgical or anesthetic risks. Our meta-analysis demonstrated that patients with SRCC who underwent RFA were usually older and had more cases of cardiovascular disease as compared with those who underwent PN. However, there was no significant difference in DM and hypertension between the two groups. Arnoux et al [33] reported the similar finding that patients who underwent RFA were older and had a higher American Society of Anesthesiologists score and a lower RENAL (Radius, Exophytic, Nearness, Anterior, Location) score compared with patients who underwent PN.

Our meta-analysis showed that the major and minor complication rate as important perioperative outcomes in RFA patients was no significant difference from that in PN patients. Johnson et al [34] reported that the major and minor complication rate of 133 cases undergoing RFA was 2.2% and 6.0%, respectively, and the most common complications were probe-site pain and paresthesia. Arnoux et al [33] revealed that the incidence of overall complications in the RFA group was significantly lower than that in the PN group (6.3% vs. 29.4%). However Carey and Hakky [35] showed no significant difference between the two groups in terms of complications.

As is known to all, renal functional preservation should be the most important goal for patients with SRCC, especially for patients with poor renal function before surgery. Pettus et al [36] found that baseline tumor size or location did not affect postoperative renal function, but preoperative eGFR did affect postoperative renal function. It was found in our meta-analysis that preoperative eGFR in the RFA group was lower than that in the PN group, whereas

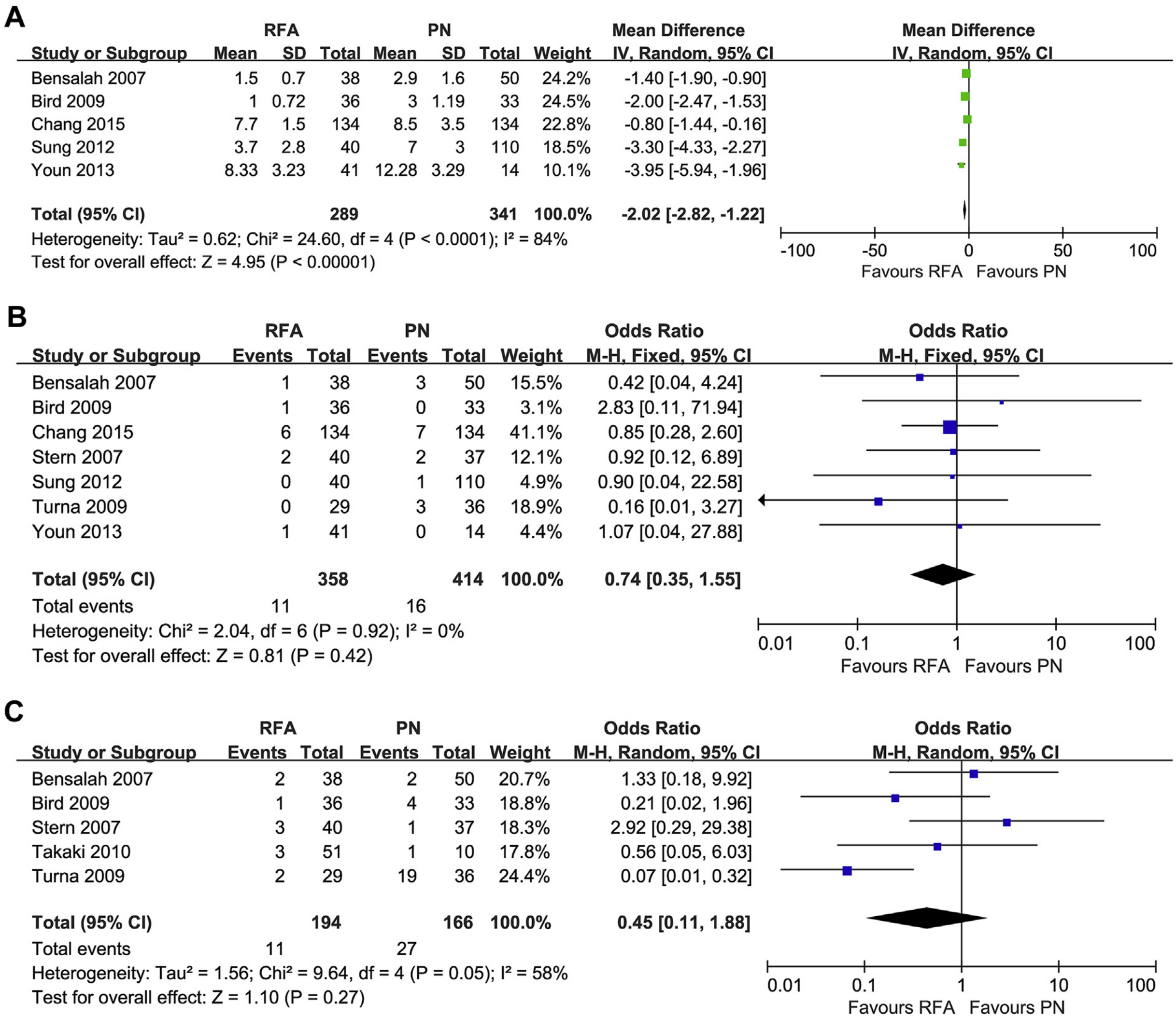


Figure 4. Pooled estimates of (A) hospital stay, (B) major complications, and (C) minor complications.

there was no significant difference in postoperative eGFR between the two groups. Interestingly, the mean decline in GFR presented a significant difference between the RFA and PN groups (RFA vs. PN: 14.8 vs. 25.5, $p = 0.04$), suggesting that RFA showed better preservation of renal function compared with PN. Similarly, in the study of Raman and colleagues [21], the maximize renal function preservation favored RFA group, and the 0-3 months and 12 months median GFP declines in RFA versus PN groups were 7.1 mL/min/1.73 m^2 versus 15.8 mL/min/1.73 m^2 and 11.2 mL/min/1.73 m^2 versus 22.4 mL/min/1.73 m^2, respectively. By contrast, Takaki et al [20] reported that the median baseline GFP in the RFA group was significantly lower than that in the PN group (49.2 mL/min/1.73 m^2 vs. 68.6 mL/min/1.73 m^2), but there was no significant difference in median GFP decline between RFA and PN groups at the last follow-up (7.9 mL/min/1.73 m^2 vs. 11.5 mL/min/1.73 m^2).

In addition, postoperative tumor control is vital to ensure the effectiveness of treatment. In all included studies, there were 43 cases (6.4%) of local tumor recurrence in the RFA group versus 53 cases (3.4%) in the PN group, suggesting that the PN oncological outcome is superior to RFA. However, there was no significant difference in the items of tumor metastasis between the two groups. A systematic review [37] reported that the local tumor recurrence rate in the RFA group was slightly higher than that in the PN group. A recent study [38] reported local tumor recurrence in two patients who underwent RFA versus none in PN. Additionally, Turna et al [23] found that the OS and CCS (91.2 and 100%) of PN group in the 2 years following were better than those (83.9 and 83.9%) of RFA group. Conversely, a long-term comparative study [19] showed that no statistical difference was found in the 5-year OS, CCS, DFS, and local RFS of RCC patients between RFA treatment and PN treatment.

Finally, financial issues are of great importance in the decision to incorporate new technologies. Generally speaking, new technologies need to spend more than the conventional standard method. Castle et al [38] reported

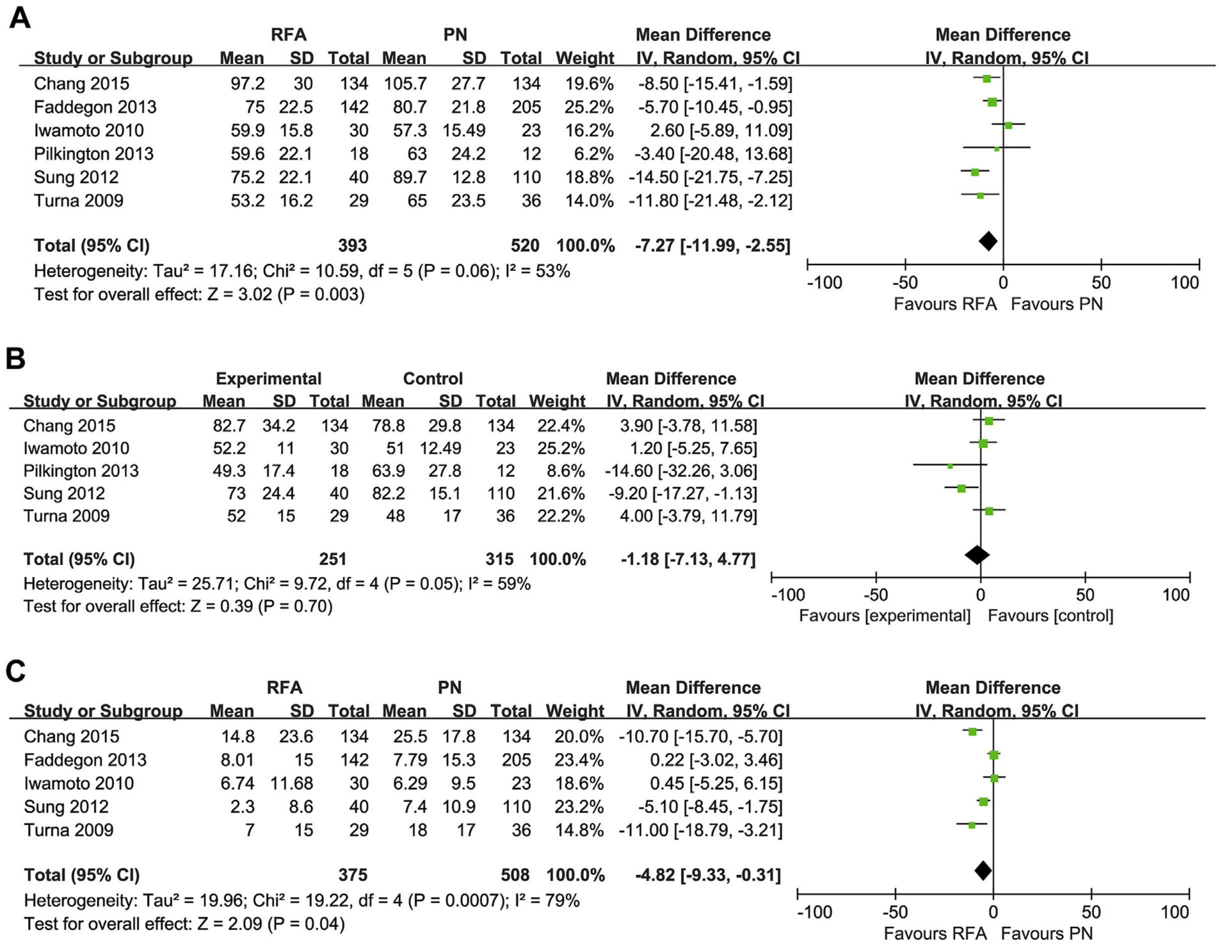


Figure 5. Pooled estimates of (A) preoperative estimated glomerular filtration rate (eGFR), (B) postoperative eGFR, and (C) eGFR decline.

that the 6-month total median cost for open partial nephrectomy (OPN), robot-assisted partial nephrectomy (RLPN), laparoscopic radiofrequency ablation, and computed tomography RFA was $17,018, $20,314, $13,965, and $6475, respectively. In other words, the cost of either laparoscopic or CT-guided RFA was lower than that of RLPN and OPN. In addition, a cost comparison study [39] showed that the mean total cost of RFA was significantly lower than that of laparoscopic PN and OPN ($4454 vs. $7767 and $7013), including surgical supplies, operating room, room and board, pharmacy, laboratory/pathology, radiology, and other professional fees. Some studies [30,40] also reported that RFA was superior to PN in item of costs in patients with SRCC.

However, there are some limitations in our study. First, all studies included in this meta-analysis were retrospective, nonrandomized, and observational studies because of the absence of prospective and randomized controlled studies. Second, some variables were unavailable to carry out meta-analysis because of the lack of standard data, such as operation duration, estimated blood loss, follow-up periods, and costs; most of these studies only provided median data, range, and interquartile range. Third, survival analysis of some included studies had no consistent standard follow-up period. Two studies provided 5-year data; two studies provided 3-year data; one study provided 2-year data; and one study provided unclear data.

The results of this study demonstrated that patients treated with RFA were older and associated with more comorbid diseases as compared with patients who underwent PN. Additionally, RFA has the advantages of a shorter length of hospital stay, lower costs, and better preservation of renal function as compared with PN, although they were equivalent in complication occurrence and renal functional preservation. The drawback of RFA is that it is associated with more local tumor recurrence. Therefore, it is important for high-risk patients to weigh the low risk of an operation against the drawback which it may bring. In brief, RFA is a suitable therapeutic option for older patients and those at high risk for SRCC because of the low risk of operation and better preservation of renal function. Prospective and randomized controlled studies are required to define the role of RFA in the management of small renal masses.

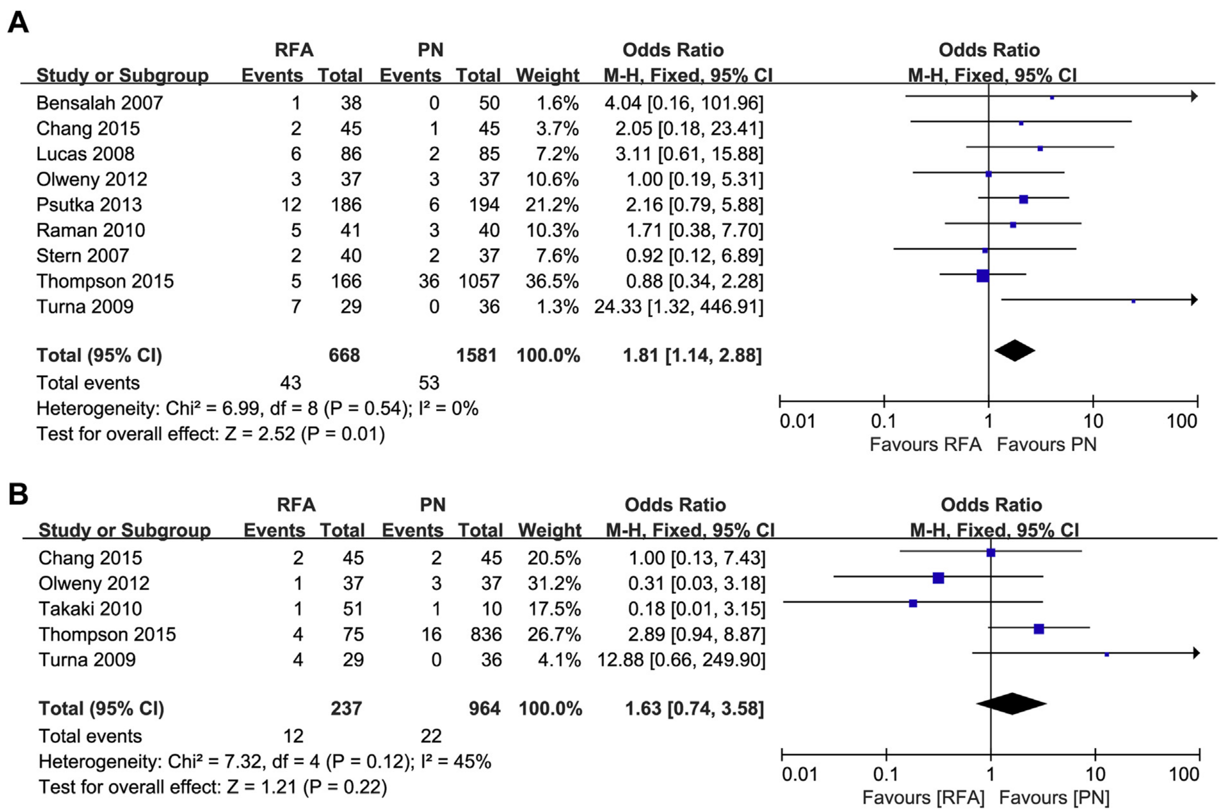


Figure 6. Pooled estimates of (A) local tumor recurrence and (B) distant metastasis.

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