US-guided Percutaneous Microwave Ablation versus Open Radical Nephrectomy for Small Renal Cell Carcinoma: Intermediate-term Results[1]

Jie Yu, MD
Ping Liang, MD
Xiao-ling Yu, MD
Zhi-gang Cheng, MD
Zhi-yu Han, MD
Xu Zhang, MD
Jun Dong, MD
Meng-juan Mu, MB
Xin Li, MD
Xiao-hui Wang, MS

Purpose: To review intermediate-term clinical outcomes of microwave ablation (MWA) compared with open radial nephrectomy (ORN) in small renal cell carcinoma (RCC) patients and to identify prognostic factors associated with two techniques.

Materials and Methods: This retrospective study was institutional review board–approved. A total of 163 patients (127 men and 36 women) with small RCC (≤4 cm) were included from April 2006 to March 2012. Sixty-five patients underwent MWA and 98 patients underwent ORN. Survival, recurrence, and renal function changes were compared between the two groups. Effect of changes in key parameters (ie, overall survival, RCC-related survival, and metastasis-free survival) was statistically analyzed with the log-rank test.

Results: Although overall survival after MWA was lower than that after ORN (P = .002), RCC-related survival was comparable to ORN (P = .78). Estimated 5-year overall survival rates were 67.3% after MWA and 97.8% after ORN; for RCC-related survival, estimated 5-year rates were 97.1% after MWA and 97.8% after ORN. There was one local tumor recurrence 32 months after MWA and none after ORN. Major complication rates were comparable (P = .81) between the two techniques (MWA, 2.5% vs ORN, 3.1%). The MWA group had less surgical time (P < .001), estimated blood loss (P < .001), and postoperative hospitalization (P < .001). Multivariate analysis showed age (P = .014), tumor type (P = .003), postoperative urea nitrogen (P = .042), comorbid disease (P = .005), and treatment modality (P < .001) may become survival rate predictors.

Conclusion: In intermediate term, ultrasonographically guided percutaneous MWA and ORN provide comparable results in oncologic outcomes. MWA appears to be a safe and effective technique for management of small RCC in patients with little loss of renal function.

[1] From the Departments of Interventional Ultrasound (J.Y., P.L., X.L.Y., Z.G.C., Z.Y.H., M.J.M., X.L.) and Urology Surgery (X.Z., J.D.), Chinese PLA General Hospital, 28 Fuxing Road, Beijing 100853, China; and Department of Ultrasound, First Affiliated Hospital of Zhengzhou University, Zhengzhou, China (X.H.W.). Received February 20, 2013; revision requested April 29; revision received August 29; accepted September 10; final version accepted Sept 20. Supported by the National Scientific Foundation Committee of China (grants 81071210 and 81127006), and International Cooperation Programs of the National Ministry of Science and Technology (grant 2012DFG32070). **Address correspondence to** P.L. (e-mail: *liangping301@hotmail.com*).

Renal cell carcinoma (RCC) accounts for 3% of malignancies in adults and 80%–90% of malignant renal tumors (1). Because of improved availability of thin-section abdominal imaging, early detection of small, low-grade RCC lesions has emerged during the last decades. Together with early detection, multiple treatment options are currently available to treat early RCCs. These treatments include traditional open radical nephrectomy (ORN) and newer nephron-sparing approaches (eg, open or laparoscopic partial nephrectomy, percutaneous thermal ablative techniques). Because of the advantages of shorter recovery times and preservation of renal function, less extensive therapies, such as percutaneous thermal ablative techniques, are gaining popularity. However, despite the trend toward the newer less-invasive approaches, ORN remains the standard treatment in the management of localized RCC for a number of indications (2).

Multiple thermal ablative modalities have been used to treat small RCCs and considerable data are available for both radiofrequency ablation (RFA) and cryoablation (3–6). Microwave ablation (MWA) is a newer modality and, therefore, less data are available for its treatment of small RCC (7–10). However, compared with RFA, MWA offers many theoretical advantages that include higher intratumoral temperatures, larger ablation volumes, less ablation time, less dependence on electrical conductivities of tissue, and that the energy delivery is less limited by the exponential rise in electrical impedance of tumor tissue (11,12). Although short-term therapeutic response and survival data have been encouraging (7–9), the role of percutaneous MWA remains a topic of controversy because there is a lack of long-term effectiveness and survival data. Furthermore, there are few comparative results of MWA with traditional ORN. Therefore, we investigated the percutaneous MWA that was guided by using ultrasonography (US) and ORN for small RCC in terms of technical effectiveness, oncologic outcomes, and complications. The purpose of our study was to review the intermediate-term effectiveness of MWA versus ORN in the management of small RCC and to identify prognostic factors associated with the use of these two techniques.

Advances in Knowledge

- For patients with small renal cell carcinomas (RCCs), there are comparable outcomes in terms of technical effectiveness and major complication rate for percutaneous microwave ablation (MWA) and open radial nephrectomy (ORN).
- RCC-related rates of survival (97.1% at 5 years) after MWA are comparable (P = .78) to those after ORN (97.8% at 5 years).

Implications for Patient Care

- MWA and ORN provide comparable results in oncologic outcomes. Therefore, in appropriately selected patient, MWA can provide an alternative, effective, minimally invasive treatment for small RCCs.
- Percutaneous MWA for small RCC needs less surgical time and has less estimated blood loss and postoperative hospitalization compared with ORN.

Materials and Methods

Patients

This retrospective study was approved by our institutional review board. Informed consent for treatment procedures was obtained from each patient. The medical records of all patients who underwent renal MWA or open surgery between April 2006 and March 2012 were reviewed. Patients with small RCC (maximum diameter, ≤4 cm) were included in the study. Patients who had RCCs with vascular invasion, extrarenal spread, or benign renal tumors were excluded. During the study period, 227 consecutive patients underwent percutaneous MWA (n = 85) and ORN (n = 142). Among them, 163 patients (mean age, 56.7 years ± 15.9; range, 6–87 years) met the inclusion criteria and were included in our study. In all, 65 patients (39.9%; 65 of 163 patients) with 69 lesions underwent MWA (the MWA group) and 98 patients (60.1%; 98 of 163 patients) with 98 lesions underwent ORN (ORN group). In the MWA group, 61 patients had single tumors and four patients had two. In our previous study (9), we reported a clinical result of MWA for RCC with 46 patients, and among them were 38 patients with small RCC. In this study, we added 27 new patients to the previously reported 38 patients with small RCC. Therefore, in our current study, a portion of the patient cohort was from a different, previously published study.

Information for each patient was obtained that included demographics, comorbidities, longest diameter of lesions, lesion numbers, pathologic type of tumor, location of lesion, and treatment variables (including postoperative hospitalization, surgical time, estimated blood loss, blood transfusion, complications, and pre- and postoperative serum creatinine and urea nitrogen levels), date and site of recurrence or metastasis, and date and status at last follow-up. We also measured and recorded reasons for death.

Published online before print
10.1148/radiol.13130275 **Content code:** IR

Radiology 2014; 270:880–887

Abbreviations:
LTP = local tumor progression
MWA = microwave ablation
ORN = open radical nephrectomy
RCC = renal cell carcinoma
RFA = radiofrequency ablation

Author contributions:
Guarantors of integrity of entire study, J.Y., P.L., X.L.Y., Z.G.C., Z.Y.H., X.Z., J.D., X.L., X.H.W.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, J.Y., P.L.; clinical studies, J.Y., P.L., X.L.Y., Z.G.C., Z.Y.H., X.Z., J.D., X.L.; statistical analysis, J.Y., M.J.M., X.H.W.; and manuscript editing, J.Y.

Conflicts of interest are listed at the end of this article.

Indications for MWA of 69 renal tumors in 65 patients were as follows: advanced age or poor surgical candidates for major comorbidities in 24 patients, poor liver function tests in five patients, single kidney after nephrectomy in six patients, poor renal function in six patients, association of other cancers in six patients, and patient preference in 18 patients. ORN was offered to patients who were relatively healthy and young enough to endure the surgery.

All patients underwent a routine physical examination, laboratory tests (blood count and serum creatinine and urea nitrogen level), and imaging studies, including chest radiography, abdominal contrast–material enhanced US, dynamic computed tomography (CT), or magnetic resonance (MR) imaging to establish the diagnosis before treatment.

The diagnosis of RCC was confirmed by pathologic findings in all patients from the ORN group. For all patients in the MWA group, RCC was diagnosed based on pathologic findings by needle biopsy of the lesion before ablation. Pathologic subtype of the tumor was classified according to the criteria advocated by Clark et al (13).

US-guided MWA

MWA was performed by three interventional radiologists (P.L., 15 years of experience in MWA, X.L.Y., 15 years of experience in MWA, and Z.G.C., 4 years of experience in MWA) with the patient under moderate sedation and local anesthesia. The microwave unit (KY-2000; Kangyou Medical, Nanjing, China) is capable of producing 100 W of power at 2450 MHz. The cooltip needle antenna had a diameter of 1.9 mm (15 gauge) and a length of 18 cm. After local anesthesia with 1% lidocaine (Yiyou, Beijing, China), US-guided biopsy was performed by an automatic biopsy gun with an 18-gauge cutting needle, and two to three separate punctures were performed. Subsequently, the antenna was percutaneously inserted into the tumor and placed at the desired location under US guidance. A power output of 50 W for 10 minutes was routinely used during MWA. After all insertions, intravenous anesthesia was administered by a combination of propofol (Diprivan; Zeneca Pharmaceuticals, Wilmington, Del) and ketamine (Shuanghe Pharmaceuticals, Beijing, China) via the peripheral vein. If the heat-generated hyperechoic water vapor did not completely encompass the entire tumor, prolonged microwave emission was applied until the desired temperature was reached.

Surgical Technique

The patients were put under either general anesthesia or continuous epidural anesthesia, and a urinary catheter was placed. ORN was performed by either a flank or a 15–20-cm subcostal incision according to standard surgical protocols by two surgeons (X.Z. and J.D., both with more than 15 years of experience in urinary surgery). Subcutaneous tissue and abdominal muscle were dissected and divided. After blunt dissection of the pararenal space to mobilize the kidney, the peritoneum was incised, and the posterior peritoneum and Gerota fascia were divided. The renal artery was clamped on approach to the hilar area. The renal vein and ureter were ligated and cut, and the renal artery was then ligated and cut. The kidney was extracted, and it was surrounded by perinephric fat and enveloped by Gerota fascia. The whole manipulation was completed with secure hemostasis. A perirenal rubber drainage tube was placed through a 5-mm port site in all of the patients for 3 or 4 days. Stitches were removed on postoperative day 8.

Follow-up

The follow-up included routine physical examination, laboratory tests (blood count and serum creatinine and urea nitrogen level), and three-phase contrast-enhanced US, CT, or MR imaging at 1 and 3 months after treatment and then at 6-month intervals for both groups. Technique effectiveness was defined as the absence of enhancement of any areas of the mass at a follow-up contrast-enhanced examination performed 1 month after treatment (14). Local tumor progression (LTP), namely local recurrence, was defined as the appearance of irregular peripheral enhancement in scattered, nodular, or eccentric pattern on contrast-enhanced images around the ablation zone in the MWA group and at the resected margin in the ORN groups during the follow-up period. Complications were defined according to RCC ablation reporting standards (13). Follow-up was closed at the time of death or the last visit of the patient.

Statistical Analysis

Comparison between the MWA and ORN group was conducted by using student t test, Wilcoxon signed rank test for continuous variables and either Pearson χ^2 test or Fisher exact test for categorical variables. Actuarially overall survival, RCC-related survival, and metastasis-free survival were calculated by using the Kaplan-Meier method and were compared by using the log-rank test. A Cox proportional hazards model was used to test for significant effects on survival rate by using multiple factors. All statistical analyses were performed by using statistical software (SPSS 16.0; SPSS, Chicago, Il). A P value less than .05 indicated statistical significance. Collection and analysis of all the data were performed by two authors (J.Y., 5 years of experience in interventional radiology, and M.J.M., 5 years of experience in internal medicine).

Results

Patient Characteristics

Physical characteristics of the patients and tumor characteristics are presented in Table 1. Patients who underwent MWA had higher mean age and associated comorbid diseases than those who received radical nephrectomy. The major comorbid diseases included associated cancer, cerebrovascular disease, cardiopulmonary disease, liver cirrhosis, renal disease or dysfunction, and diabetes in both groups. The mean tumor diameter was comparable between the two patient groups ($P = .14$). In the MWA group, RCCs were found more frequently in the middle segment of kidney ($P < .001$) and multiple tumors were more frequent ($P < .012$).

Table 1

Baseline Characteristics of Patients Undergoing MWA and ORN

Characteristic	MWA	ORN	*P* Value
Mean age (y) ± SD	65.4 ± 13.4 (30–87)	51.0 ± 14.4 (6–84)	<.001*
Sex			
Male	51	76	.89†
Female	14	22	…
Comorbid disease			
No	18	73	<.001†
Yes	47	25	…
Median follow-up (mo)	20.3 (4.3–75.2)	26.2 (4.9–79.4)	.13‡
Tumor characteristics			
Mean tumor diameter (cm) ± SD	2.7 ± 0.9 (0.6–4.0)	2.9 ± 0.8 (1.0–4.0)	.14*
Tumor no.	1.1 ± 0.3 (1–2)	1.0 ± 0 (1–1)	<.001*
Side of tumor			
Right	43	49	.12†
Left	26	49	…
Location (segment)			
Upper	9	36	<.001†
Middle	46	29	…
Lower	14	33	…
Pathologic diagnosis§			
Clear cell carcinoma	58 (89.3)	94 (96.0)	.34†
Papillary carcinoma	3 (4.6)	2 (2.0)	…
Chromophobe carcinoma	3 (4.6)	2 (2.0)	…
Cystic carcinoma	1 (1.5)	0 (0)	…
Mean total surgical time (min) ± SD	27.4 ± 2.7 (22.5–38.8)	108.2 ± 39.7 (60–300)	<.001*
Median estimated blood loss (mL)	7.5 (5.0–20.0)	100.0 (30.0–500.0)	<.001‡
Blood transfusion§	0 of 65 (0)	3 of 98 (3.1)	.41†
Mean postoperative hospitalization (d) ± SD	5.1 6 2.8 (2–18)	10.4 6 2.9 (6–22)	<.001*
Cost (yuan) ± SD	24 062.8 ± 11 755.3	27 154.9 ± 10 373.4	.08
LTP§‖	1 of 69 (1.4)	0 of 98 (0)	.41†
Technique effectiveness§#	79 of 79 (100)	98 of 98 (100)	ND
Major complications§#	2 of 79 (2.5)	3 of 98 (3.1)	.81†

Note.—Unless otherwise indicated, numbers in parentheses are the range. ND = no data, SD = standard deviation.

* Student *t* test

† Pearson χ^2 test

‡ Wilcoxon signed rank test.

§ Data in parentheses are percentages.

‖ Data are the number of lesions.

Data are the number of treatments.

Treatment Parameter

Sixty-five patients with 69 tumors received a total of 79 treatments with MWA. Fifty-nine tumors were successfully treated in one MWA session and 10 tumors were treated in two sessions. The surgical time and postoperative hospitalization for the ORN group were significantly longer than in the MWA group ($P < .001$ for both groups). There was more estimated blood loss in the ORN group ($P < .001$). Three patients in the ORN group needed blood transfusion treatment of 400–600 mL. Transfusion was not necessary in the MWA group.

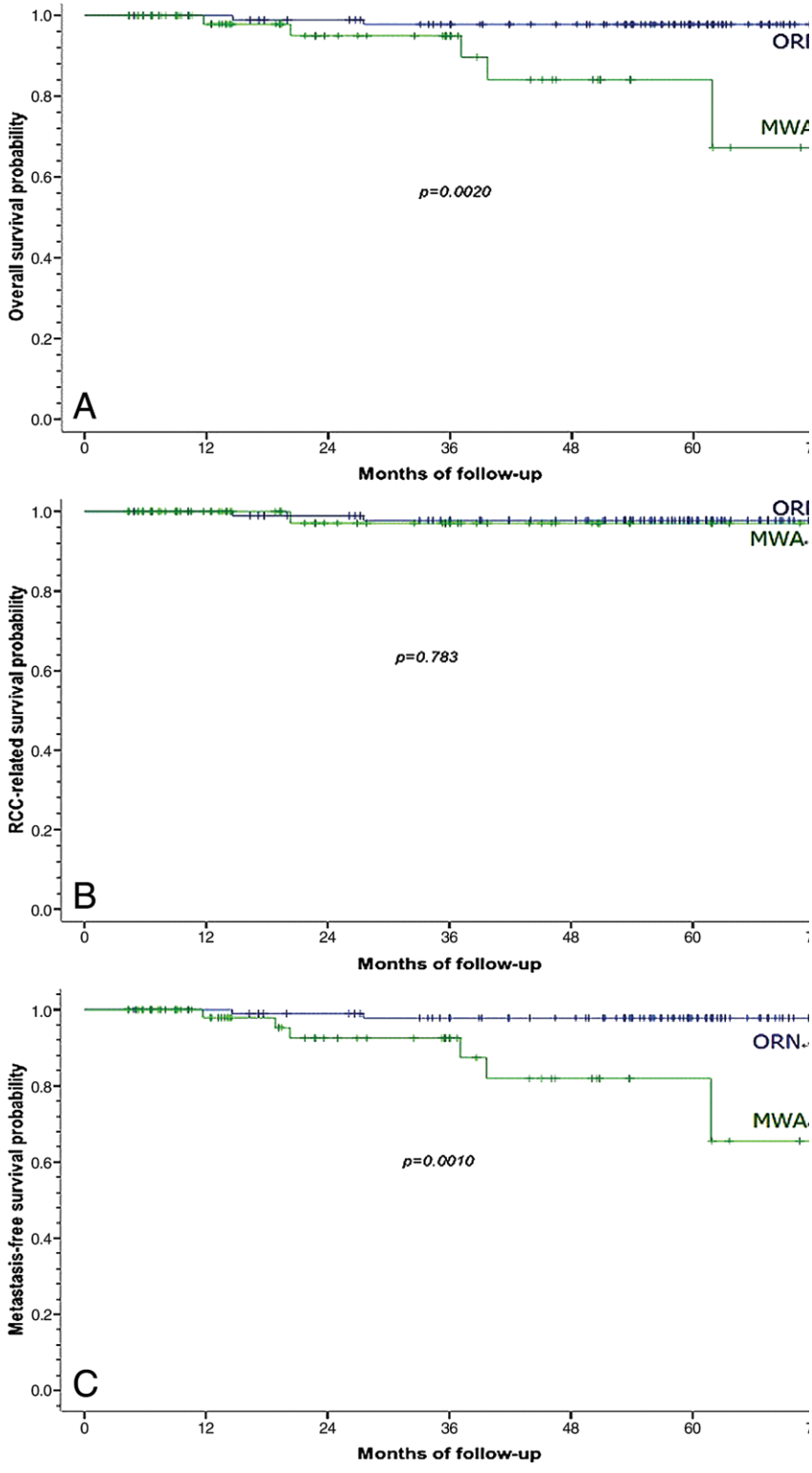
Midterm Oncologic Outcome and Recurrence

The median follow-up periods were 20.3 months (4.3–75.2 months) in the MWA group and 26.2 months (4.9–79.4 months) in the ORN group. Five patients died (7.7%; five of 65 patients) in the MWA group. Causes of death for these five patients were primary liver cancer progression, heart failure, liver failure, stomach bleeding, and RCC local and systemic progression. Four of the patients had comorbid diseases, including primary liver cancer in one patient (the liver tumor had been ablated when RCC was treated), cerebrovascular disease in one patient, and liver cirrhosis in two patients. Two patients (2.0%; two of 98 patients) died in the ORN group, and the cause of death in both was RCC local and systemic progression.

On the basis of follow-up imaging, 100% technique effectiveness was achieved in both groups (MWA: 79 of 79 treatments; ORN: 98 of 98 treatments). One LTP lesion was discovered at 32 months after MWA with a 2.7-cm ablated nodule. No LTP lesions were discovered after ORN treatment. Two patients (3.1%; two of 65 patients) after MWA and three patients (3.1%; three of 98 patients) after ORN had distant metastases. The 1-, 3-, and 5-year overall survival rates of MWA and ORN groups were 97.9%, 89.7%, 67.3% and 99.0%, 97.8%, and 97.8%, respectively (Fig 1a), showing significant statistical difference ($P = .002$). The 1-, 3-, and 5-year RCC-related survival rates of MWA and ORN groups were 97.1%, 97.1%, 97.1% and 99.0%, 97.8%, and 97.8%, respectively (Fig 1b), showing no significant statistical difference ($P = .78$). The 1-, 3-, and 5-year metastasis-free survival of MWA and ORN groups were 97.9%, 87.4%, and 65.5% and 99.0%, 97.8%, and 97.8%, respectively (Fig 1c), showing significant statistical difference ($P = .001$). All the survival *P* values were obtained from the log-rank test for the entire curves.

Univariate and Multivariate Analysis

The influence of patient and tumor-related factors on survival is shown in Table 2. The results showed statistically significant differences in survival rates depending on the age of the patient ($\chi^2 = 6.80$; $P = .03$) and the presence



A, Graph shows cumulative overall survival rates after each treatment. The 1-, 3-, and 5-year overall survival rates were, respectively, 97.9%, 89.7% and 67.3% in the MWA group and 99.0%, 97.8%, and 97.8% in the ORN group. The overall survival rates of ORN group were better than those of MWA group ($P = .002$). *B,* Graph shows cumulative RCC-related survival rates after each treatment. The 1-, 3-, and 5-year RCC-related survival rates of the MWA group were comparable to those of the ORN group ($P = .78$). *C,* Graph of cumulative metastasis-free survival rates after each treatment. The 1-, 3-, and 5-year metastasis-free survival rates were, respectively, 97.9%, 87.4%, and 65.5% in the MWA group and 99.0%, 97.8%, and 97.8% in the ORN group, which showed significant statistical difference ($P = .001$).

of extrarenal metastasis ($\chi^2 = 26.20$; $P < .001$).

A multivariate analysis was performed by using the variables that were assessed in the univariate analysis. The multivariate analysis (Table 3) showed that several factors related to the survival rate, including age ($P = .014$), tumor type ($P = .003$), postoperative urea nitrogen ($P = .042$), comorbid disease ($P = .005$), and treatment modality ($P < .001$), presented significant hazard tendency. Seven patient deaths in the two groups were diagnosed as clear cell carcinoma; five of these patients had comorbidities and four patients were older than 70 years.

Complications and Renal Function Changes

No death was directly related to any treatment. Two major complications (2.5%; two of 79 patients) occurred in the MWA group after 79 MWA sessions, including one patient who had hepatic encephalopathy with liver dysfunction and one urinary fistula in a patient who had diabetes and a high-risk tumor location adjacent to the renal collecting system. Three major complications (3.1%, three of 98 patients) occurred in cases of ORN group after 98 surgical procedures, including two incision ruptures and one incision hernia. Two of those patients had hypertension and one patient did not

Table 2

Univariate Analysis of Prognostic Factors for Overall Survival

Variable	No. of Patients	No. of Deaths	χ^2 Value	*P* Value
Men	127	5	0.002	.97
Women	36	2	…	…
Age				
≤45 years	36	1	6.80	.03*
46–65 years	80	1	…	…
>65 years	46	5	…	…
No comorbid disease	91	2	1.20	.27
Comorbid disease	72	5	…	…
Tumor type				
Clear cell carcinoma	152	7	0.53	.91
Papillary carcinoma	5	0	…	…
Chromophobe carcinoma	5	0	…	…
Cystic carcinoma	1	0	…	…
Single tumor	159	7	0.67	>.999
Multiple tumors	4	0	…	…
Tumor diameter				
≤2 cm	33	1	1.34	.51
2.1–3 cm	61	4	…	…
3.1–4 cm	73	2	…	…
Normal preoperative serum creatinine	155	7	0.10	>.999
Abnormal preoperative serum creatinine	8	0	…	…
Normal preoperative serum urea nitrogen	147	7	0.06	>.999
Abnormal preoperative serum urea nitrogen	16	0	…	…
Normal postoperative serum creatinine	104	6	0.69	.41
Abnormal postoperative serum creatinine	59	1	…	…
Normal postoperative serum urea nitrogen	126	7	1.01	.32
Abnormal postoperative serum urea nitrogen	37	0	…	…
LTP				
Present	2	0	2.11	>.999
Absent	161	7	…	…
Extrarenal metastasis				
Present	5	3	26.20	<.005*
Absent	158	4	…	…
Major complications				
Present	5	0	0.41	>.999
Absent	158	7	…	…
Treatment modality				
ORN	5	0	0.41	>.999
MWA	158	7	…	…

* Univariate Kaplan-Meier analysis.

have comorbid disease. The patient who had hepatic encephalopathy was successfully treated with intravenous hepatoprotective medicine for 1 week, and the patient who had urinary fistula was cured with intravenous antiinfection and antidiabetes medicine for 10 days. ORN complications were all successfully treated by suturing the incision a second time. The overall complication rates for the two groups were comparable (P = .81).

The changes in renal function are presented in Table 4. Patients in the MWA group had higher preoperative serum creatinine level (P = .007) and lower immediately postoperative (24–48 hours) serum creatinine level (P < .001) than did patients in the ORN group. However, the preoperative serum urea nitrogen level of the ORN group was higher (P = .001), and postoperative urea nitrogen levels of the two groups were comparable (P = .07). The MWA group had less variation of serum urea nitrogen level (P < .001).

Discussion

Because of increased incidence of RCC and because in more patients with RCC the RCCs are detected at an early stage (1,15,16), multiple approaches are becoming popular for RCC treatment, including radial nephrectomy, partial nephrectomy, wedge resection, and in situ thermal ablation. ORN, described by Robson et al (17), has been the standard treatment for RCC. Nevertheless, because of the increased use of abdominal imaging modalities together with early detection of tumor, less invasive therapies and minimally invasive therapies have developed and are gaining popularity. Despite this evolution, there is still a place and usage trend for open surgery for localized RCC (18). As a mature minimally invasive ablation, RFA for small RCCs, especially for poor surgical candidates, achieved favorable long-term results and had LTP less than 5% and disease-free survival of more than 92% (3,4). Cryoablation also resulted in acceptable intermediate-term oncologic efficacy with a tolerable complication profile in selected patients with small RCC (5,6). Comparative research of RFA with cryoablation versus ORN for RCC treatment is limited. The literature (18,19) shows no significant difference in cancer-specific survival between RFA with cryoablation and ORN.

Compared with RFA, MWA may allow a larger ablation zone and higher intratumoral temperatures. MWA is also less affected by the perfusion-mediate heat-sink effect, which may help to treat tumors in kidney tissue and has blood flow approximately four times that of the liver (11,20,21). Though one recent study by Castle et al (10) reported

Table 3

Multivariate Analysis of Prognostic Factors with Cox Proportional Hazards Model

Variable	β Level	Standard Error	Wald	*P* Value	Odds Ratio (β Level)	95% Confidence Interval
Sex	−.159	0.271	0.345	.557	.853	0.501, 1.450
Age	−.021	0.009	6.023	.014	.979	0.963, 0.996
No. of tumors	.972	0.598	2.644	.104	2.642	0.819, 8.522
Tumor diameter	.177	0.130	1.839	.175	1.193	0.924, 1.541
Tumor type	1.116	0.371	9.058	.003	3.052	1.476, 6.313
Preoperative creatinine	.006	0.007	0.654	.419	1.006	0.992, 1.019
Preoperative urea nitrogen	−.029	0.079	0.133	.715	.972	0.832, 1.134
Postoperative creatinine	−.006	0.005	1.268	.260	.994	0.983, 1.005
Postoperative urea nitrogen	.116	0.057	4.128	.042	1.123	1.004, 1.255
Comorbid disease	−.763	0.272	7.885	.005	.466	0.274, 0.794
Extrarenal metastasis	−.085	0.459	0.034	.853	.918	0.374, 2.258
LTP	−.316	1.183	0.071	.789	.729	0.072, 7.410
Major Complications	.074	0.488	0.023	.879	1.077	0.414, 2.803
Treatment modality	2.321	0.462	25.218	<.001	.190	4.118, 25.214

Table 4

Changes in Renal Function

Parameter	MWA Group (n = 65)	ORN Group (n = 98)	*P* Value*
Median preoperative serum creatinine (μmol/L)	80.0 (39–614.7)	76.1 (40.3–799.9)	.007
Median preoperative serum urea nitrogen (mmol/L)	6.9 (3.1–24.9)	7.2 (2.4–11.1)	.001
Median postoperative serum creatinine (μmol/L)	119.9 (40.3–799.9)	132.5 (53.7–376.1)	<.001
Median postoperative serum urea nitrogen (mmol/L)	6.8 (3.1–20.9)	6.2 (3.3–18.0)	.07
Variation of serum creatinine (μmol/L)	5.1 (0–249.7)	5.7 (3.5–157.5)	<.001
Variation of serum urea nitrogen (mmol/L)	0.09 (0–5.5)	1.4 (0.2–10.7)	<.001

Note.—Data in parentheses are ranges.

* Wilcoxon signed rank test.

disappointing results with a relatively larger tumor size (mean, 3.65 cm) for 50% of the tumors involved in the renal collecting system, several other studies (7–9) reported encouraging results of MWA for small RCC in local tumor control and short-term survival. Furthermore, MWA can achieve comparable short-term results to those obtained by using RFA or cryoablation in small RCC. However, long-term effectiveness, survival data of MWA patients, and comparative results of MWA with traditional surgery are lacking.

In our study, patients who underwent MWA had a significantly higher mean age, more tumors, and more associated comorbid diseases than those who underwent ORN. Shorter surgical and hospitalization time, lower costs, less estimated blood loss, and no blood transfusion after MWA were advantageous for reducing perioperative morbidity and nonurologic complications. Major complications in the MWA group were comparable to those of the ORN group. The MWA group had higher preoperative serum creatinine level, lower immediately postoperative serum creatinine level, less variation of serum urea nitrogen level after treatment, and less renal deterioration.

Also in our analysis, data on the oncologic outcome have to be interpreted with caution because of the relatively short follow-up (median, 2 years), small patient cohort, and higher comorbidities of MWA group. Technical effectiveness and local tumor control seem to be two important factors to achieve results similar to those after surgical intervention. The only LTP patient was the first case treated with the MWA technique in our study, and this patient was given laparoscopic nephrectomy as a successful salvage therapy. This may be related to less experience at the beginning of MWA. Our data suggest that MWA and ORN yield comparable RCC-related survival efficacy in small RCC. However, the ORN group showed favorable results in overall survival and metastasis-free survival. MWA treatment presented more death cases; however, 80.0% (four of five patients) of them had and died of comorbidities, which may be a leading cause of unfavorable prognosis.

An important limitation of our study is its retrospective design with a relatively small patient series. Limited sample size might have reduced statistical power in comparative analysis so that some associations were not detected. The limited follow-up cannot provide long-term oncologic results for the two techniques. Also, the success of MWA was assessed by radiographic findings versus pathologic margin-free status. Therefore, despite the intermediate follow-up reported, it might take longer to use radiographic techniques to detect MWA failures. Finally, included in our population were patients with small RCC, defined as having tumors less than 4 cm, which excluded larger and more advanced tumors in which MWA is not usually performed. A prospective trial that compares standard procedures with MWA is needed to validate the role of this developing modality in the clinical field.

In conclusion, MWA and ORN provided comparable results in terms of technical effectiveness, oncologic outcomes, and complications. These results are promising and serve as a useful framework for future prospective and randomized trials that compare MWA and surgery for the treatment of RCC.

Disclosures of Conflicts of Interest: J.Y. No relevant conflicts of interest to disclose. **P.L.** No relevant conflicts of interest to disclose. **X.L.Y.** No relevant conflicts of interest to disclose.

Z.G.C. No relevant conflicts of interest to disclose. **Z.Y.H.** No relevant conflicts of interest to disclose. **X.Z.** No relevant conflicts of interest to disclose. **J.D.** No relevant conflicts of interest to disclose. **M.J.M.** No relevant conflicts of interest to disclose. **X.L.** No relevant conflicts of interest to disclose. **X.H.W.** No relevant conflicts of interest to disclose.

References

1. Jemal A, Siegel R, Ward E, Murray T, Xu J, Thun MJ. Cancer statistics, 2007. CA Cancer J Clin 2007;57(1):43–66.
2. Vander Eeckt K, Joniau S, Van Poppel H. Open surgery for localized RCC. ScientificWorldJournal 2007;7:742–752.
3. Psutka SP, Feldman AS, McDougal WS, McGovern FJ, Mueller P, Gervais DA. Long-term oncologic outcomes after radiofrequency ablation for T1 renal cell carcinoma. Eur Urol 2013;63(3):486–492.
4. Takaki H, Nakatsuka A, Uraki J, et al. Renal cell carcinoma: radiofrequency ablation with a multiple-electrode switching system—a phase II clinical study. Radiology 2013;267(1):285–292.
5. Duffey B, Nguyen V, Lund E, Koopmeiners JS, Hulbert J, Anderson JK. Intermediate-term outcomes after renal cryoablation: results of a multi-institutional study. J Endourol 2012;26(1):15–20.
6. Beemster PW, Barwari K, Mamoulakis C, Wijkstra H, de la Rosette JJ, Laguna MP. Laparoscopic renal cryoablation using ultrathin 17-gauge cryoprobes: mid-term oncological and functional results. BJU Int 2011;108(4):577–582.
7. Liang P, Wang Y, Zhang D, Yu X, Gao Y, Ni X. Ultrasound guided percutaneous microwave ablation for small renal cancer: initial experience. J Urol 2008;180(3):844–848; discussion 848.
8. Carrafiello G, Mangini M, Fontana F, et al. Single-antenna microwave ablation under contrast-enhanced ultrasound guidance for treatment of small renal cell carcinoma: preliminary experience. Cardiovasc Intervent Radiol 2010;33(2):367–374.
9. Yu J, Liang P, Yu XL, et al. US-guided percutaneous microwave ablation of renal cell carcinoma: intermediate-term results. Radiology 2012;263(3):900–908.
10. Castle SM, Salas N, Leveillee RJ. Initial experience using microwave ablation therapy for renal tumor treatment: 18-month follow-up. Urology 2011;77(4):792–797.
11. Brace CL. Radiofrequency and microwave ablation of the liver, lung, kidney, and bone: what are the differences? Curr Probl Diagn Radiol 2009;38(3):135–143.
12. Yu J, Liang P, Yu X, Liu F, Chen L, Wang Y. A comparison of microwave ablation and bipolar radiofrequency ablation both with an internally cooled probe: results in ex vivo and in vivo porcine livers. Eur J Radiol 2011;79(1):124–130.
13. Clark TW, Millward SF, Gervais DA, et al. Reporting standards for percutaneous thermal ablation of renal cell carcinoma. J Vasc Interv Radiol 2009;20(7 Suppl):S409–S416.
14. Goldberg SN, Grassi CJ, Cardella JF, et al. Image-guided tumor ablation: standardization of terminology and reporting criteria. Radiology 2005;235(3):728–739.
15. Ferlay J, Parkin DM, Steliarova-Foucher E. Estimates of cancer incidence and mortality in Europe in 2008. Eur J Cancer 2010;46(4):765–781.
16. Ljungberg B, Campbell SC, Choi HY, et al. The epidemiology of renal cell carcinoma. Eur Urol 2011;60(4):615–621.
17. Robson CJ, Churchill BM, Anderson W. The results of radical nephrectomy for renal cell carcinoma. 1969. J Urol 2002;167(2 Pt 2):873–875; discussion 876–877.
18. Choueiri TK, Schutz FA, Hevelone ND, et al. Thermal ablation vs surgery for localized kidney cancer: a Surveillance, Epidemiology, and End Results (SEER) database analysis. Urology 2011;78(1):93–98.
19. Takaki H, Yamakado K, Soga N, et al. Mid-term results of radiofrequency ablation versus nephrectomy for T1a renal cell carcinoma. Jpn J Radiol 2010;28(6):460–468.
20. Brown DB. Concepts, considerations, and concerns on the cutting edge of radiofrequency ablation. J Vasc Interv Radiol 2005;16(5):597–613.
21. Wright AS, Sampson LA, Warner TF, Mahvi DM, Lee FT Jr. Radiofrequency versus microwave ablation in a hepatic porcine model. Radiology 2005;236(1):132–139.