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Review Article

Microwave Ablation of T1a and T1b Renal Masses: A Retrospective Study

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Abstract

The aim of this study was to evaluate the efficacy and safety of microwave ablation (MWA) for the treatment of T1a and T1b renal masses, with size ranges between 1.2 and 6.5 cm. A retrospective review was performed at a single tertiary comprehensive cancer center between June 2019 and June 2023 of 49 consecutive patients (53 total procedures) who underwent MWA for renal masses. The Solero microwave tissue ablation system (Angiodynamics, Latham, NY, United States) was utilized. Patient demographics, renal mass characteristics, and procedural outcomes were collected. Serum creatinine and estimated glomerular filtration rate (eGFR) were utilized to assess renal functional outcomes. Oncologic outcomes were assessed using evidence of local tumor recurrence on contrast-enhanced cross-sectional imaging, local recurrence-free probability at 1 and 2 years, and overall survival (OS) using the Kaplan–Meier analysis. Forty-nine patients (57% males and 43% females) with a median age of 72 years (range, 38–84 years) underwent 53 MWA procedures. The mean renal mass size was 2.8 ± 0.94 cm (range, 1.2–6.5 cm). *Most of the renal tumors were T1a*. Three of the 53 *total renal tumors* were *larger than 4 cm* (T1b) and the *remaining 50* were *less than 4 cm in size* (T1a). The *largest tumor* that was ablated was *6.5 cm* in size. All the patients were *placed under general anesthesia* (intubated) before the MWA procedure. A median microwave energy of 100 W (range, 60–140 W) was used. The mean duration of the MWA was 3.9 ± 1.5 minutes, with a 100% technical success rate. Four patients (8.2%) experienced complications, two (4.1%) of whom experienced a major complication. There was no clinically significant change in renal function from pre- to postablation on day 1 or at 3 months. Furthermore, local tumor recurrence was observed in three (6.1%) patients at 2.5, 15, and 25 months postablation. Local recurrence-free probability was 98 and 93% at 1 and 2 years, respectively. The OS was 98 and 87% at 1 and 2 years, respectively. MWA continues to prove to be an effective technique that can be used to

Keywords
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- retrospective analysis
- renal masses

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treat small renal masses including oncocytomas, with high technical success, low complication rate, low risk of adverse renal functional outcomes, and encouraging results for sustained tumor control.

Introduction

Renal masses can be managed with partial or radical nephrectomy or thermal ablation. The current guidelines from the American Urological Association outlines thermal ablation as an alternative treatment for cT1a renal masses less than 3 cm, with radiofrequency ablation (RFA) and cryoablation (CA) as the suggested modalities.[1] Microwave ablation (MWA) is a newer technology than RFA or CA that offers several benefits: higher intratumoral temperatures, larger and more predictable tumor ablation volumes, and efficient ablation times.[2] Although promising studies are emerging describing MWA for T1a (<4 cm) and T1b (4–7 cm) renal masses,[3–6] consensus is yet to be established for the role of MWA in the treatment algorithm. MWA of small renal masses remains understudied compared with older and more established technologies of RFA and CA.

This study's purpose was to perform a retrospective review of a series of patients who underwent MWA for small renal masses to evaluate its efficacy and safety by assessing renal functional, procedural, and oncologic outcomes.

Methods

Data Collection and Statistical Analysis

An institutional review board (IRB) approved retrospective review was performed for patients with small renal masses treated with MWA at the University of Iowa Hospitals and Clinics, a tertiary academic center, between June 2019 and June 2023. Data were collected on patient demographics, renal mass size, and pathology for patients who underwent image-guided biopsy prior to MWA. *Most biopsies* were taken a few *days to weeks before* the ablation procedure. Biopsy of the mass was not obtained in all cases based on patient preferences for masses with sufficient radiologic evidence of the pathology. Procedural variables collected included microwave energy used (watts), ablation duration times (minutes), and technical success rate. Renal functional outcomes were assessed using pre- and postablation creatinine values, and pre- and postablation estimated glomerular filtration rate (eGFR). Creatinine values were measured pre- and postablation day 1, and eGFR was measured pre- and postablation day 1, and at 3 months. Pre- versus postablation percent changes in laboratory values were assessed using linear regression models fitted with the method of generalized estimating equations to account for repeated MWA for some patients. Postablation complications were classified using the Society of Interventional Radiology (SIR) Adverse Event (AE) classification. Pre- and postablation hemoglobin (Hb) values were compared with assess for significant procedure-related hemorrhage. Oncologic outcomes were assessed by identifying the rate of local tumor recurrence on follow-up imaging. After MWA, most patients underwent follow-up imaging with computed tomography (CT) or magnetic resonance imaging (MRI) with contrast at 6 weeks postprocedure, then every 6 months for 2 years, and annually thereafter. *Primary treatment efficacy* was defined as *absence of nodular enhancement or growth of tumor* on the first follow-up CT, with *enhancement* being defined as a *change of greater than 10 HU* and *growth* defined as any *increase in size* compared with the baseline imaging. *Disease recurrence* was associated with the *development of new nodular enhancement* on follow-up CT after a negative baseline CT. The Kaplan–Meier method was used to estimate local recurrence-free probability and overall survival. Survival estimates were reported along with 95% confidence intervals (CIs). Patients who did not experience a survival event were censored at the end of their imaging follow-up for local recurrence-free probability, and at the last known date alive for OS. All reported *p*-values are for two-sided tests of statistical significance.

Microwave Ablation Procedure

MWA with CT guidance was performed by a team of *one urologist and two board-certified interventional radiologists* with over 10 years of experience in the field (performed over 100 procedures). The technique followed procedural instructions similar to those mentioned in a prior publication about MWA.[2] Patients were positioned prone on a procedural table and an initial helical scan with skin grid was performed to identify the renal mass location and mark the area of interest on the basis of baseline imaging. Under CT guidance, the ablative probe(s) was/were passed into the target lesion (median: 2; range: 1–2). There was no need for ancillary techniques such as *hydrodissection* or *pyeloperfusion* during any of the ablation procedures. Once the probe(s) reached the target, intravenous (IV) contrast (1 mL/kg) was injected to confirm appropriate needle placement within the center of the tumor before subsequent ablation. Ablation parameters were based on the lesion size, and treatment algorithms were determined by the manufacturer's (Solero Microwave Tissue Ablation System, Angiodynamics, Latham, NY, United States) suggested settings with a planned ablation margin of at least 5 mm. Either a 14- or 19-cm, 15-gauge probe was utilized based on skin to tumor distance.

All patients were admitted to the hospital overnight for observation following the procedure. *Labs were monitored throughout* the patient's hospital stay. Creatinine, eGFR, and Hb were particularly monitored after the MWA procedure on postablation day 1, and eGFR was also measured at the 3-month clinic follow-up. The patients were followed up with cross-sectional contrast-enhanced imaging. *Experienced*

radiologists with more than 10 years of experience at the hospital carefully *analyzed these images* to determine the tumor's response to the treatment.

Results

Patient and Renal Mass Characteristics

Forty-nine patients (57% male, 43% female) underwent 53 MWA procedures during the study period. A total of 28 patients (57%) had biopsy-proven renal cell carcinoma (RCC), with 21/28 (75%) having clear cell type RCC and 7/28 (25%) having papillary type RCC. Three patients (6.1%) had biopsy-proven oncocytoma. Out of the remaining 18 patients (36.7%), 11 patients had imaging characteristics of RCC with nondiagnostic biopsies, and 7 patients (14% of total patients) had imaging characteristics of RCC. *RCC tumors* showed *significant enhancement* on CT scan, usually more than 20 HU. However, *diagnosing benign tumors*, particularly renal oncocytomas (ROs), is often *challenging*. ROs and RCCs often have *similar imaging features* like being well circumscribed and hypervascular. Therefore, a *biopsy was done* to rule out RCC. Considering the *significant similarities in imaging features with malignant tumors* such as RCC and that *biopsies of ROs* are *not necessarily accurate*, ROs were *treated with MWA* depending on the patient's preference. There were nine patients (18%) who had a history of RCC, treated with either radical nephrectomy on the contralateral side of the ablated kidney ($n = 1$, 11.1%) or partial nephrectomy of the same kidney that was ablated ($n = 8$, 88.9%). Four patients (8.1%) had prior renal MWA treatment. No patients were diagnosed with metastatic cancer. Patient demographics are summarized in ►**Table 1**.

Procedural Outcomes

The technical success rate of MWA in this cohort was 100%. The median microwave energy applied was 100 W per procedure (range, 60–140 W). The mean duration of ablation was 3.9 ± 1.5 minutes. The mean pre-ablation renal mass size was 2.8 ± 1.0 cm. The mean postablation size was 2.1 ± 0.9 cm. Renal mass size decrease after ablation was 27.5 ± 13.0%. The mean distance of the tumor from the closest adjacent calyx was 4.7 ± 4.0 mm; of note, 33% of masses were located very close to the calyceal system, defined as located within 4 mm of the collecting system. The *mean skin to lesion distance* was 7.06 ± 2.32 cm. The *median skin to lesion distance* was 7.09 cm. The combined minor and major complication rate was 8.2% for 53 procedures performed. Both early (within 24 hours of the procedure) and late complications (>1 month after the procedure) were evaluated. Two patients (4.1%) developed acute kidney injury (AKI) on postablation day 1. One patient was medically managed and had resolution of AKI within 1 week of the procedure. The second patient, who had a baseline stage 3b chronic kidney disease (CKD) and proteinuria secondary to diabetes mellites, progressed to renal failure, which was characterized by a sustained increase in creatinine values up to 12 months after the procedure, resulting in stage 4 CKD. Two patients (4.1%) developed moderate to large subcapsular hematomas, both discovered on follow-up CT 1 month after the procedure, one of which required interventional radiology drain placement to relieve compression and improve renal perfusion. The remaining patients did not experience any late complications. On postablation day 1 there was a clinically insignificant decline in Hb of 4.4 ± 6.9% (0.59 ± 0.93 g/dL; $p < 0.001$). Furthermore, there was no clinically significant change in renal function from pre- to postablation at day 1 or 3 months. The median eGFR was 65.0 mL/min/1.73 m^2 (range: 50.0–79.5) and 65.0 mL/min/1.73 m^2 (range: 45.5–80.5) at day 1 and 3 months, respectively. The median creatinine was 1.10 mg/dL (range: 0.90–1.40) and 1.10 mg/dL (range: 0.90–1.24) at 1 day and 3 months, respectively. The median creatinine was 1.10 mg/dL (range: 0.90–1.40) and 1.10 mg/dL (range: 0.90–1.24) at 1 day and 3 months, respectively.

Table 1 Patient demographics and renal mass pathology

Characteristic	Ratio (percentage)
Male, *n* (%)	28/49 (57)
Female, *n* (%)	21/49 (43)
Mean age in years (range)	69.9 (38–84)
Biopsy-proven renal cell carcinoma (**RCC**)	28/49 (57%)
Clear cell RCC	21/28 (75%)
Papillary RCC	7/28 (25%)
History of nephrectomy	9/49 (18%)
Complete nephrectomy	1/49 (2%)
Partial nephrectomy	8/49 (16%)

Renal Functional Outcomes

Serum creatinine and eGFR values were available for assessment for 49 patients pre- and postablation day 1 and for 47 patients 3 months after the procedure. Pre- and postablation creatinine and eGFR values, along with percent change, are shown in ►**Table 2**. The mean pre-ablation creatinine was 1.32 ± 0.98 mg/dL; postablation day 1 creatinine measured 1.38 ± 1.03 mg/dL; and creatinine at 3 months postablation measured 1.35 ± 1.05 mg/dL. There was a 5.2% increase in creatinine on postprocedure day 1 ($p = 0.019$) and a 4.6% increase in creatinine 3 months postprocedure compared with the preprocedure level ($p = 0.027$). Two patients experienced AKI following the procedure. However, there was no statistically significant change in eGFR on postprocedure day 1 ($p = 0.61$) or at 3 months after the procedure ($p = 0.51$).

Oncologic Outcomes

The mean duration of follow-up for this cohort was 23.1 ± 15.9 months. Local recurrence-free probability was assessed with follow-up data up to 43 months. OS was assessed with follow-up data up to 61 months. Three patients (6.4%) developed recurrent viable tumor on subsequent surveillance examinations. Estimated local recurrence-free

Table 2 Summary of renal function values

Parameter	Median (IQR)
Pre-ablation serum creatinine (mg/dL)	1.07 (0.90–1.30)
Pre-ablation eGFR (mL/min/1.73m^2)	65.0 (52.0–82.0)
Post-ablation serum creatinine (mg/dL)	1.10 (0.90–1.40)
Post-ablation serum creatinine at 3 mo (mg/dL)	1.10 (0.90–1.24)
Post-ablation eGFR (mL/min/1.73m^2)	65.0 (50.0–79.5)
Post-ablation eGFR at 3 mo (mL/min/1.73m^2)	65.0 (45.5–80.5)
Percent change of parameter	**% change (*p*-value)**
Percent change (pre- vs. postablation) creatinine	5.2 (0.019)
Percent change (pre- vs. 3 mo postablation) creatinine	4.6 (0.027)
Percent change (pre- vs. postablation) GFR	−0.9 (0.61)
Percent change (pre- vs. 3 mo postablation) GFR	−1.2 (0.51)

Abbreviations: eGFR, estimated glomerular filtration rate; GFR, glomerular filtration rate; IQR, interquartile range.

and OS probabilities are plotted in ►**Fig. 1** and ►**Fig. 2**. Recurrence-free probability at the 1- and 2-year marks, respectively, was 98 and 93%; OS at the 1- and 2-year marks, respectively, was 98 and 87% (►**Table 3**). ►**Fig. 3** shows left kidney renal mass prior to ablation and 1 year post-MWA. ►**Fig. 4** shows a large right kidney renal mass before ablation and 1 year post-MWA on CT urogram.

Discussion

Renal MWA is a safe and effective alternative to more established techniques such as RFA and CA for the treatment of small renal masses such as RCC.[7] Although compelling data have been published on RFA and CA, comparatively less literature describes the safety and efficacy profile of MWA for small renal masses. Our study adds to existing literature on MWA of small renal masses by characterizing procedural outcomes, including renal mass characteristics and percentage change in renal mass size after MWA, as well as characterizing renal functional and oncologic outcomes. In our retrospective review, we found a 100% technical success rate for MWA. Technical success rates for MWA, RFA, and CA in the treatment of small renal masses are all high. Pandolfo et al reported a technical success rate of 100% for MWA and 98.5% for CA and RFA.[8] The range of skin to lesion distances found in this study also demonstrates that this procedure can be done in patients of a wide range of body habitus. The mean renal mass size in this cohort decreased by 27.5% following ablation on the imaging follow-up in our study ($p < 0.001$). There are sparse data quantifying shrinkage in renal mass size following MWA, RFA, or CA. Previous studies have suggested that MWA lesions show significant shrinkage due to desiccation at the time of the procedure, whereas CA lesions tend to regress over time, and RFA lesions show minimal shrinkage.[9,10]

The overall complication rate in this study was 8.2% for a total of 53 procedures. Complication rates following MWA have been reported to be 1.8% for major complications, and up to 17.5% for minor complications.[11] Guo and Arellano reported a complication rate of 8.7% in a single-center retrospective review of 23 patients with T1b RCC treated with CT-guided percutaneous MWA.[12] Comparatively, Ito

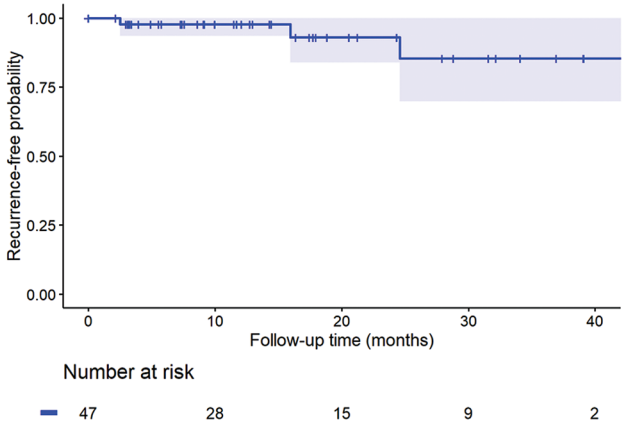

Fig. 1 Kaplan–Meier curve of estimated local recurrence-free probability (95% CI) over a period of 43 months for 47/49 patients.

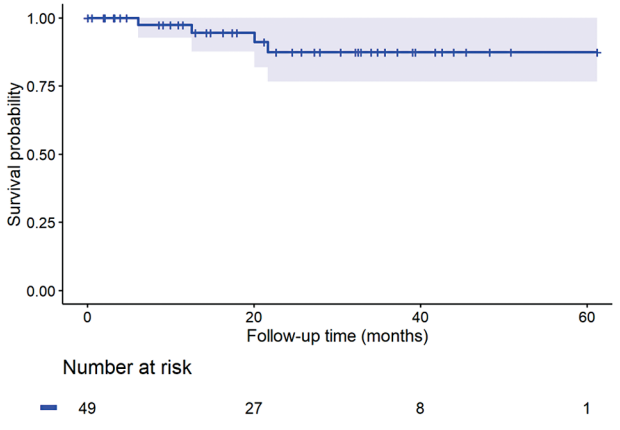

Fig. 2 Kaplan–Meier curve of overall survival probability (95% CI) over a period of 61 months.

Table 3 Estimated local recurrence-free and overall survival probabilities (95% CI) at 1 and 2 years for 47/49 patients

	Recurrence-free probability		Survival probability	
Time	1 y	2 y	1 y	2 y
Overall	98% (94–100%)	93% (84–100%)	98% (93–100%)	87% (77–100%)

Abbreviation: CI, confidence interval.

et al reported a complication rate of 10% for a series of 40 patients who underwent RFA for small size RCC.[13] In an outlier, Thompson et al described a major complication rate of 11.5%, including postoperative bleeding, and two cases of ureteropelvic junction stricture.[14] There is sparse, but increasing, literature comparing complication rates between MWA, CA, and RFA; some studies show equivalent complication rates, while others suggest MWA to be a safer modality compared with RFA and CA.[11,15] Interestingly, in comparing CA, RFA, and MWA, Pandolfo et al showed that CA/RFA had a significantly longer procedural time compared with MWA in the treatment of small renal masses; they did not note any significant difference in either intraprocedural or postprocedural complications.[8] In this study, the risk of procedural bleeding was also low: there was no clinically significant change in Hb postablation day 1, although two patients did develop delayed perinephric hematoma. One-third of lesions treated were within 4 mm of the collecting system, and no urine leaks or significant urinary collecting system injuries were observed.

MWA has been shown to be safe for preserving renal function. In this study, there was a statistically significant percentage change in creatinine pre-ablation and 1 day postablation (5.2%, $p = 0.019$), as well as at 3 months (4.6%, $p = 0.027$). Changes in eGFR were not clinically significant. The mean postablation creatinine increased by only 0.06 mg/dL and the mean postablation creatinine at 3 months increased by only 0.03 mg/dL. Two patients did experience AKI, one of whom had a baseline CKD stage 3 that progressed to stage 4. In our overall patient pool, there was no statistically significant change in eGFR on postablation day 1, or at the 3-month follow-up. These findings are consistent with a prior multicenter analysis by Pandolfo et al who also observed no adverse impact on kidney function up to 1 year after MWA.[8]

Local tumor recurrence-free probability was at 98% at 1 year and 93% at 2 years, similar to rates published in the literature. Yu et al reported a 1-, 2-, and 3-year disease-free survival rates of 100, 100, and 97.8%, respectively.[16] Yu et al subsequently reported a 5-year cancer-specific survival rate of 91.4%, disease-free survival of 69.1%, and OS of 89.2%.[17] Guo and Arellano showed a local tumor progression-free survival of 100.0, 90.9, and 90.9% at 1, 2, and 3 years, respectively[12]; notably, this study included 12 T1b tumors.

Limitations of this study include it being a single-center retrospective study, lacking prospective randomization to facilitate comparison with RFA and CA, and a low rate of biopsy-proven RCC. The treatment strategy for each patient was identified with interprofessional, multidisciplinary decision-making, which made randomization not feasible. Although 42 of 49 (86%) patients treated underwent biopsy prior to ablation, only 57% of patients had biopsy-proven RCC, which may limit extrapolation of results to patients with other types of renal tumors or metastatic lesions. Patients lacking pathologic data limit evaluation of long-term oncologic outcomes; however, their short-term outcomes remain important with respect to measuring technical success, complications, and postoperative renal function. *Another limitation* of this manuscript is the *absence of calculated nephrometry scores* for the patients, which would have shed light on the difference in treatment methods of complex and simple tumors.

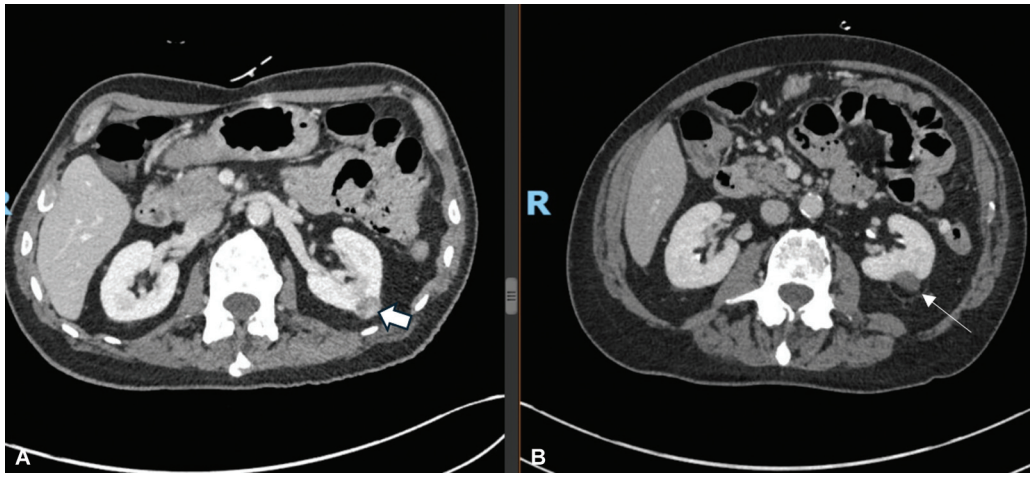

Fig. 3 Representative images of renal tumors **(A)** pre- and **(B)** postablation. Renal mass (thick arrow); post ablation (thin arrow).

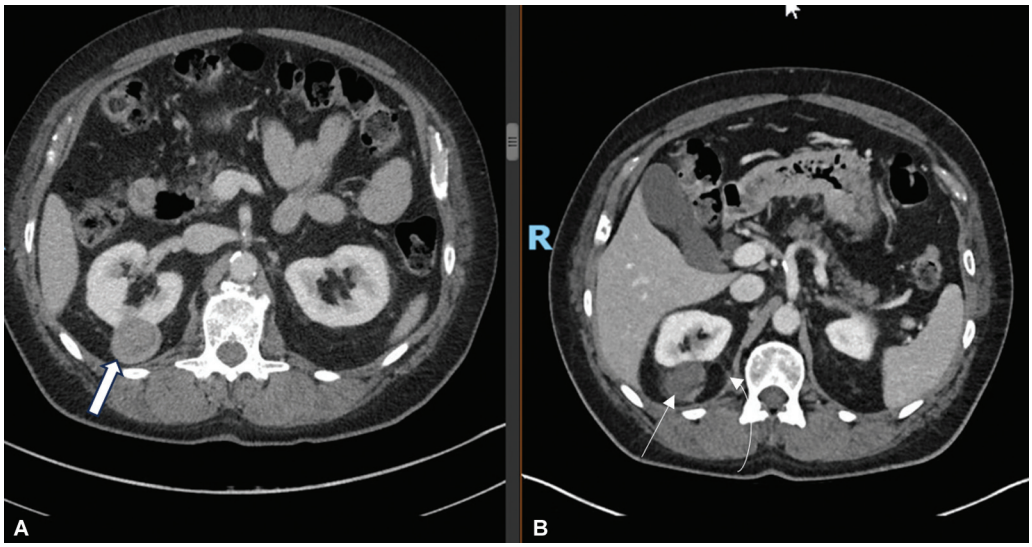

Fig. 4 Representative images of renal tumors **(A)** pre- and **(B)** postablation. Renal mass, preablation (thick arrow); renal mass postablation (thin arrow); postablation halo (curved arrow).

Conclusion

MWA continues to prove to be an effective technique that can be used to treat small renal masses including oncocytomas, with high technical success, low complication rate, low risk of adverse renal functional outcomes, and encouraging results for sustained tumor control. Nevertheless, *comparative studies* (RFA, MWA or CA) or *prospective studies* would be needed in the future.

Ethical Approval

This is an institutional review board (IRB) approved study that is retrospective in terms of human subjects' regulatory definition. The study is restricted to the University of Iowa Hospitals and Clinics data. All the authors hereby declare that there are no conflicts of interests to disclose.

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None.

Conflict of Interest

None declared.

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