AJR FOCUS ON:

Percutaneous Image-Guided Thermal Ablation for Multifocal Renal Cell Carcinoma: 10-Year Experience at a Single Center

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OBJECTIVE. The objective of our study was to assess the technical success, safety, and oncologic and renal function outcomes of CT-guided percutaneous thermal ablation for synchronous multiple renal masses in a single session.

MATERIALS AND METHODS. A retrospective analysis of 23 patients (16 men and 7 women; median age, 70 years) with biopsy-proven multifocal renal cell carcinoma (RCC) masses treated with radiofrequency ablation (RFA), cryoablation, or microwave ablation (MWA) was performed. Preablation, postablation, and follow-up serum blood urea nitrogen, creatinine, and estimated glomerular filtration rate (GFR) levels were recorded to evaluate the stability of renal function. Technical success, complications, treatment response, oncologic outcome, and overall survival were assessed.

RESULTS. Biopsy-proven RCCs were treated in 23 patients. Median tumor size was 2.3 cm (range, 1.0–4.0 cm). The mean RENAL (radius, exophytic vs endophytic properties, nearness of tumor to the collecting system or sinus, anterior vs posterior, location relative to polar lines) nephrometry score was 6.3 (range, 4.0–10.0); mean PADUA (preoperative aspects and dimensions used for anatomical) score, 7.8 (range, 6.0–11.0); and mean centrality index (C-index), 3.1 (range, 0.7–6.8). The mean ablation time was 23 minutes (range, 3–24 minutes). Technical success was achieved for 100% of tumors. Of the 49 complications, nine (18%) were classified as Clavien-Dindo grade I complications. Complete response was achieved in 41 of the 49 (84%) tumors. Local progression-free, RCC-specific disease-free, and overall survival rates during the imaging follow-up time (mean, 3.1 years; range, 0.1–9.6 years) were 96% (22/23), 100% (23/23), and 91% (21/23), respectively.

CONCLUSION. CT-guided percutaneous thermal ablation is a safe, effective, and durable treatment intervention for multifocal renal masses.

Keywords: cryoablation, microwave ablation, radiofrequency ablation, renal cell carcinoma

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Renal cell carcinoma (RCC) is one of the most common malignancies in the United States [1]. The diagnosis of RCC is now primarily driven by incidental detection during routine medical imaging [2]. Although solitary lesions represent most cases, multifocal RCC occurs in up to 5% of patients, including patients with hereditary conditions such as von Hippel–Lindau syndrome, Birt-Hogg-Dubé syndrome, and tuberous sclerosis complex [3, 4]. These conditions classically predispose affected individuals to multiple RCCs, but sporadic nonhereditary multifocal disease is also commonly seen [3, 4]. Despite therapeutic advances for solitary RCC [5], management of multifocal RCC remains a challenge. Therapeutic interventions must find a balance between tumor eradication and preservation of renal function. Although no standard treatment protocol exists for multifocal RCC, surgery is often considered as the first-line therapy [6, 7]; however, resection of multiple RCCs can be technically challenging, which can increase perioperative complications and lead to worsening renal function [3, 8–10].

Image-guided tumor ablation is a minimally invasive procedure for the treatment of a number of solid tumors [11]. Recently, a paradigm shift to nonsurgical therapies of small renal masses (< 4 cm) favors the use of thermal ablation with radiofrequency ablation (RFA) or cryoablation over surgical methods [12, 13]. Accumulating data support thermal ablation as providing equivalent oncologic outcomes relative to nephrectomy for small localized RCC with safer perioperative outcomes and comparable nephron preservation [14–16]. Although thermal ablation is an acceptable option for small unifocal RCC, its role in sporadic multifocal disease is unclear. In the current study, we report our experience at a single institution to evaluate the technique, safety, and renal function and tumor outcomes of CT-guided thermal ablation for multifocal RCC.

Materials and Methods

The institutional review board approved this HIPAA-compliant retrospective study with a waiver of informed consent. Between October 2005 and August 2016, 23 adult patients (16 men and 7 women; mean age, 70 years; age range, 22–88 years) underwent CT-guided RFA, cryoablation, or microwave ablation (MWA) for multiple renal masses in a single session. Patients had preoperative CT or MRI and percutaneous biopsy results to establish the diagnosis of RCC, so all treated tumors were biopsy-proven RCC. Medical records were reviewed to determine patient baseline characteristics according to the Eastern Cooperative Oncology Group (ECOG) performance status and American Society of Anesthesiologists (ASA) classification system.

Patient Selection

Patients with RCC referred by the urology department were evaluated to assess performance status and determine treatment planning. The choice of thermal ablation modality was made on a case-by-case basis and was based on operator preference. Tumor characteristics including tumor size, location, and subtypes were reviewed; tumor nephrometry scores were tabulated, with risk stratifications using the following three previously described scoring systems [17]: RENAL (radius, exophytic vs endophytic properties, nearness of tumor to the collecting system or sinus, anterior vs posterior, location relative to polar lines) nephrotomy score, PADUA (preoperative aspects and dimensions used for anatomical) score, and centrality index (C-index).

Thermal Ablation Techniques

All RFAs were performed using 17-gauge internally cooled clustered electrode applicators (Covidien Cool-tip RF Ablation System and Switching Controller, Medtronic). Cryoablations were performed using cryoprobes that were 1.3–3.8 mm in diameter (PerCryo and Endocare Cryocare System, HealthTronics). MWAs were performed with 14- or 16-gauge antennae using an MWA system (Amica, HS Medical) that operates at 2.45 GHz.

Hydrodissection or pyeloperfusion was performed for selected cases to protect organs and tissues at risks of thermal injuries [18]. Patients with an ASA score ≤ 2 received sedation, and those with an ASA score of ≥ 3 received general anesthesia. Procedural data were collected; in addition, pre- and postablation blood urea nitrogen (BUN) values, creatinine levels, and estimated glomerular filtration rates (GFRs) to assess the stability of renal function were compared. Immediate and 30-day complications were assessed and classified according to the Clavien-Dindo classification system and the Society of Interventional Radiology guidelines.

Assessment of Treatment Results and Clinical Follow-Up

Technical success was defined as completion of the scheduled treatment. Follow-up surveillance CT or MRI examinations were performed at intervals of 1, 3, and 6 months and annually thereafter. Treatment response was evaluated using the Response Evaluation Criteria in Solid Tumors (RECIST) [19]. Repeat thermal ablation was performed when follow-up imaging showed residual disease or partial response by RECIST. Local tumor progression was defined as a new focal enhancement detected in the ablation zone on follow-up imaging.

Statistical Methods

Statistical analyses were performed using a statistics software package (Prism, version 7, GraphPad Software). The Fisher exact test was used to evaluate any association between clinical variables and local recurrence outcomes; in addition, relative risk with the corresponding 95% CI using the Koopman asymptotic score was computed. A one-way ANOVA repeated-measures analysis with Greenhouse-Geisser correction was performed to assess estimated GFR changes and stage-specific chronic kidney disease (CKD) changes after multifocal thermal ablation. The Kaplan-Meier method estimated overall survival, progression-free survival, RCC-specific disease-free survival, and survival free of new-onset stage-specified CKD outcome. Patients whose records were missing postablation or last follow-up estimated GFRs were excluded from analyses of these endpoints. All statistical tests reported were two-tailed, where p values < 0.05 were considered statistically significant.

Results

Twenty-three patients with 49 RCCs were included in the study group. Table 1 summarizes patient and tumor characteristics. Median age was 70 years, (range, 22–88 years). All but four patients had ASA scores ≤ 2; the majority of patients (17/23, 74%) had ECOG performance status of ≤ 1. Median tumor size was 2.3 cm (range, 1.0–4.0 cm). Of the 49 tu-

TABLE 1: Characteristics at Baseline of 23 Patients and 49 Tumors in Study Cohort

Characteristic	Value
Sex, no. of patients	
Male	16
Female	7
Age (y), median (range)	70 (22–88)
BMI[a], mean (range)	31.4 (24.0–43.7)
ASA score ≤ 2[b]	19 (83)[c]
ASA score > 2[b]	4 (17)[c]
ECOG score ≤ 1[b]	17 (74)[c]
ECOG score > 1[b]	6 (26)[c]
Mean no. of tumors per patient	2.13
Patients with more than two tumors ablated	2 (9)[c]
Tumor size (cm), median (range)	2.3 (1.0–4.0)
Tumor category	
T1a	48 (98)[d]
T1b	1 (2)[d]
Tumor laterality, no. of tumors	
Right	25
Left	24
Tumor location	
Upper pole	16 (33)[d]
Midpole	19 (39)[d]
Lower pole	14 (28)[d]
Tumor anatomy	
Exophytic	24 (49)[d]
Endophytic	18 (37)[d]
Mixed	7 (14)[d]
Tumor subtype	
Clear cell	32 (65)[d]
Papillary	11 (22)[d]
Chromophobe	4 (8)[d]
RCC, NOS	2 (4)[d]
RENAL nephrometry score	
Mean (range)	6.3 (4.0–10.0)
Low (score = 4–6)	25 (51)[d]
Moderate (score = 7–9)	21 (43)[d]
High (score = 10–12)	3 (6)[d]
PADUA nephrometry score	
Mean (range)	7.8 (6.0–11.0)
Low (score = 6–7)	25 (51)[d]
Moderate (score = 8–9)	7 (14)[d]
High (score = 10–14)	17 (35)[d]

(Table 1 continues on next page)

TABLE 1: Characteristics at Baseline of 23 Patients and 49 Tumors in Study Cohort (continued)

Characteristic	Value
C-index	
Mean (range)	3.1 (0.7–6.8)
Low (C-index > 2.0)	32 (65)[d]
High (C-index < 2.0)	17 (35)[d]
Tumor adjacent to[e]	
Bowel	11 (22)[d]
Ureter	6 (12)[d]
Sinus fat	4 (8)[d]
Pancreas	3 (6)[d]
Psoas muscle	1 (2)[d]

Note—BMI = body mass index; ASA = American Society of Anesthesiologists; ECOG = Eastern Cooperative Oncology Group; RCC = renal cell carcinoma; NOS = not otherwise specified; RENAL = radius, exophytic versus endophytic properties, nearness of tumor to the collecting system or sinus, anterior versus posterior, location relative to polar lines; PADUA = preoperative aspects and dimensions used for anatomical; C-index = centrality index.
[a]Weight in kilograms divided by the square of height in meters.
[b]American Joint Committee on Cancer.
[c]Data are reported as number (%) of patients.
[d]Data are reported as number (%) of tumors.
[e]Adjacency is defined as tumor located 5 mm or less from organ or tissue specified.

mors, 48 (98%) were classified as localized (N0M0) T1a, and one (2%) was classified as T1b. The histologic subtypes of most tumors were clear cell (32/49, 65%) and papillary (11/49, 22%). The mean RENAL nephrometry score was 6.3 (range, 4.0–10.0), mean PADUA nephrometry score was 7.8 (range, 6.0–11.0), and mean C-index was 3.1 (range, 0.7–6.8).

Procedural data are summarized in Table 2. The mean number of ablations per tumor was 2.0. Thirteen of 49 (27%) tumors required more than two overlapping ablations; 16 (33%) tumors, two overlapping ablations; three (6%) tumors, one overlapping ablation; and 17 (35%) tumors, 0 overlapping ablations. Stratification based on ablation modality revealed that RFA was associated with more frequent overlapping ablations than cryoablation or MWA. The mean ablation time per tumor was 23 minutes (range, 3–84 minutes); 32 of 49 (65%) tumors required two or more overlapping ablations.

Adjuvant maneuvers were used in 19 of 49 (39%), including hydrodissection in 16 (33%) and pyeloperfusion in three (6%). IV procedural sedation was used for 19 of 23 (83%) patients, and the remaining four patients (17%) received general anesthesia due to preexisting cardiovascular, cardiopulmonary, or metabolic disorder comorbidities that precluded sedation.

There were nine of 49 (18%) Clavien-Dindo grade I complications. All nine were small perinephric hematomas that were managed conservatively (Fig. 1). There was one Clavien-Dindo grade IIIa complication; it was a urinoma that was managed by percutaneous drainage (Fig. 2). Relative risk analysis revealed increased risk of complications in patients with a high C-index, RENAL score, and PADUA score (Fig. 3). Laboratory analysis of renal function showed no significant deterioration or CKD progression; there was no new onset of stage IV CKD, but CKD in three patients with existing stage IV CKD eventually advanced to end-stage renal disease (Fig. 4).

Technical success was 100%. At 1-month imaging follow-up, complete response was achieved in 41 of 49 (84%) tumors (Fig. 5). Partial response was achieved in eight of 49 (16%) tumors. These partial response cases were retreated to achieve complete response, for an overall complete response rate of 100%. Relative risk analysis revealed increased risk of residual disease in patients with a high RENAL score, PADUA score, and C-index (Fig. 6). Oncologic outcomes are summarized in Table 3.

Mean imaging follow-up time was 3.1 years (range, 0.1–9.6 years). During the imaging follow-up period, one patient developed distant metastases at 4.8 months after ablation. Twenty-one of 23 (91%) patients are alive and disease-free; the remaining two patients died after 1.5 and 5.8 years of follow-up of causes unrelated to thermal ablation or

TABLE 2: Procedural Data

Procedural Data	Value
Needle approach	
Posterior	23 (47)[a]
Lateral	26 (53)[a]
Ablation modalities	
RFA	30 (61)[a]
Cryoablation	6 (12)[a]
MWA	13 (27)[a]
Mean no. of ablations per tumor	
All thermal ablation procedures	2.0
RFA	2.5
Cryoablation	1.7
MWA	1.1
Tumors treated with overlapping ablations	32 (65)[a]
0	17 (35)[a]
1	3 (6)[a]
2	16 (33)[a]
> 2	13 (27)
Mean ablation time per tumor (range), min	
All thermal ablation procedures	23 (3–84)
RFA	29 (12–84)
Cryoablation	28 (28–28)
MWA	8 (3–15)
Mean procedural time per patient (range), min	
All thermal ablation procedures	129 (30–250)
RFA	155 (60–250)
Cryoablation	141 (100–165)
MWA	70 (30–110)
Anesthesia care	
Conscious sedation	19 (83)[b]
General anesthesia	4 (17)[b]
Adjuvant maneuvers	21 (43)[a]
Hydrodissection	16 (33)[a]
Pyeloperfusion	3 (6)[a]
Technical success	49 (100)[a]
Complications	10 (20)[a]
Hematoma	9 (18)[a]
Urothelial injury	1 (2)[a]
Classifications of complications	
SIR classification A–B	9 (18)[a]
SIR classification C–F	1 (2)[a]
Clavien-Dindo grade I	9 (18)[a]
Clavien-Dindo grade II–IV	1 (2)[a]

Note—RFA = radiofrequency ablation, MWA = microwave ablation, SIR = Society of Interventional Radiology.
[a]Data are reported as number (%) of tumors.
[b]Data are reported as number (%) of patients.

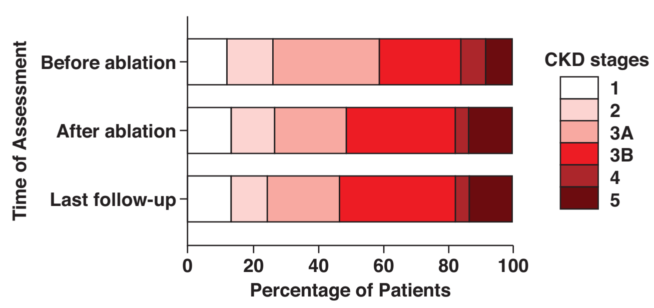


Fig. 1—Clustered column graph shows chronic kidney disease (CKD) stages in study cohort of 23 patients with multifocal renal cell carcinoma (RCC) before and after thermal ablation of multifocal RCC and at last follow-up. CKD severity is categorized on basis of National Kidney Foundation's kidney disease outcomes quality initiative classification system.

TABLE 3: Treatment Response and Oncologic Outcomes

Results and Follow-Up Data	Value
Complete response[a]	41 (84)[b]
Partial response[a]	8 (16)[b]
Retreatment achieved complete response	8 (100)[b]
Follow-up (y), mean (range)	3.1 (0.1–9.6)
Residual tumor on initial follow-up imaging	8 (16)[c]
Locally recurrent disease	2 (4)[b]
Time to recurrence (y), mean (range)	4.8
Metastatic progression	2 (4)[b]
Time to metastasis (y), mean (range)	1.5
Death due to cause other than RCC	2 (9)[c]
Disease-free survival	96[d]
Progression-free survival	96[d]
Overall survival	91

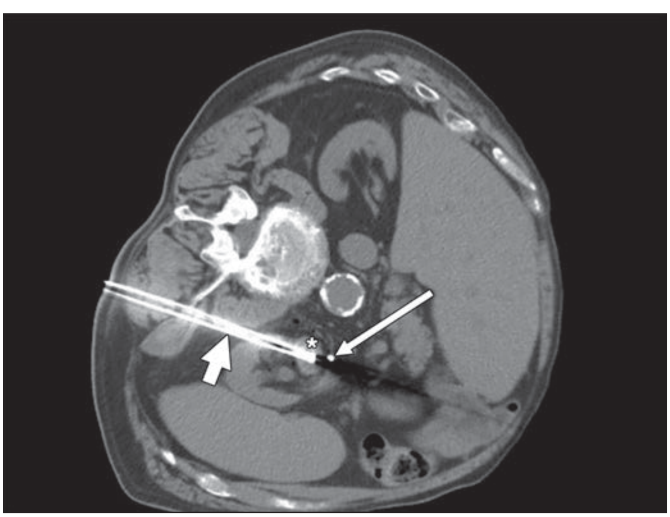
Note—RCC = renal cell carcinoma.
[a]As defined by Response Evaluation Criteria in Solid Tumors.
[b]Data are reported as number (%) of tumors.
[c]Data are reported as number (%) of patients.
[d]Data are reported as percentages of patients.

RCC. Local progression-free, RCC-specific disease-free, and overall survival rates during the imaging follow-up were 96% (22/23), 100% (23/23), and 91% (21/23) (Fig. 7).

Discussion

Multifocal RCC remains a challenge regarding optimal management strategies. Contrary to well-described cases involving hereditary conditions or unifocal lesions [12], no standard management algorithm exists for sporadic multifocal RCC. Although surgical management offers acceptable oncologic outcomes [6, 7, 20], simultaneous or multiple operations inherently exacerbate the risks of perioperative complications, mortality, and diminished renal function [3, 8–10]. Minimally invasive thermal ablation may represent an attractive nonsurgical alternative; in fact, thermal ablation is routinely used for multifocal liver masses with favorable clinical outcomes [21]. However, the lack of evidence hinders the adoption of the use of this potentially beneficial therapy for multifocal RCC. We present the collective results of 10 years of experience to comprehensively assess the safety and oncologic and function renal outcomes of thermal ablation in patients with sporadic multifocal RCC.

Multifocal RCC tumors represent distinctly complex disease that poses a significant dilemma in detecting disease, selecting therapeutic interventions, and determining prognosis. Multifocal RCC generally carries a poor prognosis, in part reflecting high pathologic grade, extensive tumor necrosis, and increased propensity for local recurrence [22]. Although the incidence, clinicopathologic features, and prognostic factors are well described [22], less is known about treatment outcome and therapeutic advances beyond nephron-sparing surgery. In the current study, we have shown the technical feasibility of thermal ablation of multiple RCC lesions in a single session, which yielded an overall technical success of 100%. When objectively assessing treatment response using RECIST, thermal ablation achieved complete response after the initial treatment in 84% (41/49); partial response was observed in 16% (8/49) of tumors after initial treatment, and all cases of partial response were associated with tumor diameter larger than 4 cm. Nevertheless, repeat ablations for residual disease achieved complete response. Importantly, all of the patients achieved RCC-specific disease-free survival with only one case of local progression and distant me-



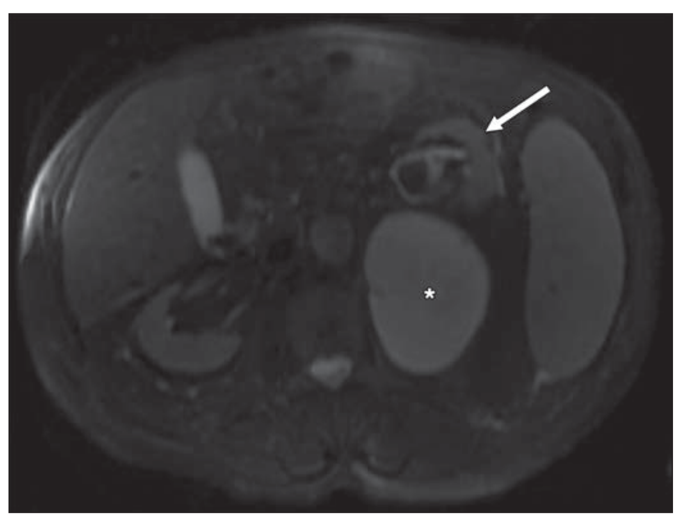


Fig. 2—72-year-old man who presented with multifocal renal cell carcinoma (RCC).
A, Axial unenhanced CT scan of abdomen obtained during radiofrequency ablation (RFA) shows cluster RFA electrode (*short arrow*) in centrally located RCC (*asterisk*). Long arrow indicates left ureteral stent within left ureter. Patient is in left lateral decubitus position.
B, Axial T2-weighted fast spin-echo image of abdomen obtained 3 months after RFA for left RCC (*asterisk*) shows left retroperitoneal urinoma. Left kidney is displaced anteriorly by urinoma (*arrow*).

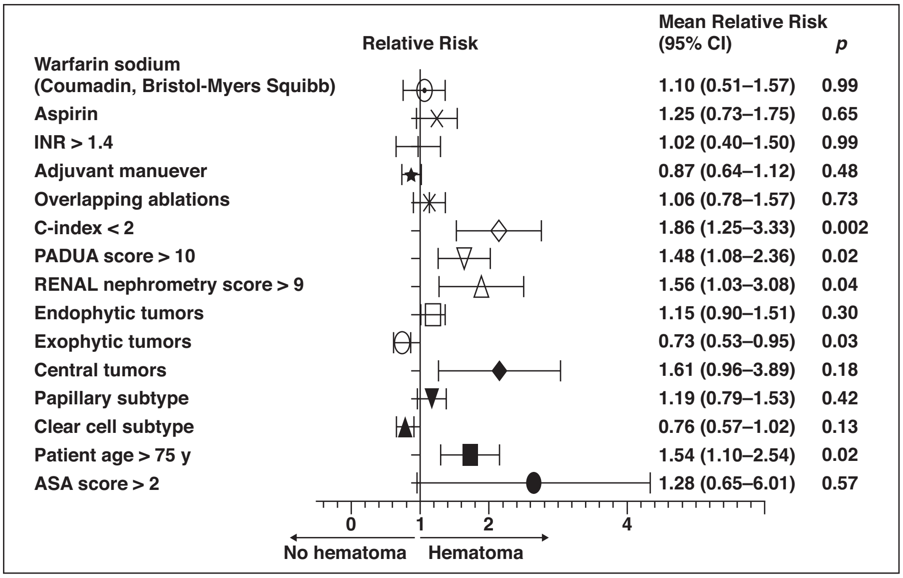


Fig. 3—Relative risk analysis to identify predictors of complications after thermal ablation of multifocal renal cell carcinoma (RCC). Forest plot is shown to compare outcomes of hematoma versus no hematoma on basis of individual patient, tumor, and procedural variables. Vertical line shows no relative risk. For each variable, whiskers show standard error, and symbols show mean relative risk value. INR = international normalized ratio; C-index = centrality index; PADUA = preoperative aspects and dimensions used for anatomical; RENAL = radius, exophytic versus endophytic properties, nearness of tumor to the collecting system or sinus, anterior versus posterior, location relative to polar lines; ASA = American Society of Anesthesiologists.

tastasis on surveillance imaging with a mean follow-up period of 4.2 years (range, 1–11 years). Remarkably, multifocality and the larger tumor diameter did not significantly worsen patient oncologic outcome.

Thermal ablation is equally effective when comparing outcomes for unifocal and multifocal RCC, providing similar technical success, therapeutic response, overall survival, and disease-free survival rates [18, 23]. Further stratification based on histologic subtype, tumor size, and tumor location revealed that similar therapeutic efficacy and tumor control could be achieved by thermal ablation irrespective of single versus multiple renal masses. The therapeutic efficacy of thermal ablation may be explained in part by its induction of systemic antitumor immune response. For instance, several pilot studies have shown promising results of thermal ablation in combination with chemotherapy and surgery [11]. Furthermore, the increasingly recognized benefits of the abscopal effect from locoregional therapies could elicit favorable antitumor immune surveillance to protect patients with multifocal disease from developing de novo or locally recurrent tumors.

Preservation of renal function is the utmost concern for patients with multifocal renal masses, given that multiple or repeat invasive interventions may lead to renal insufficiency. Growing evidence reveals the adverse impact of chronic renal impairment on general health and overall survival [24]; most notably, renal function reduction dramatically exacerbates the risk of major cardiovascular events and death [24]. Despite surgical extirpation as the conventional procedure of choice, patients who undergo nephrectomy are at risk of deteriorating renal function and are predisposed to end-stage renal failure, even if treated using conservative approaches with nephron-sparing surgeries [25]. By contrast, minimally invasive thermal ablation leverages imaging guidance for precise in situ tumor obliteration with distinct advantages: minimum destruction of functioning nephrons and maximum preservation of the renal parenchyma. Although thermal ablation of solitary RCC may not significantly alter renal function status [16], it remains unclear whether the same outcome can be achieved with multiple tumor ablations. In the current study, no significant declines were observed in three renal outcome measures (i.e., estimated GFR, creatinine value, and BUN value) when comparing baseline values and values obtained at follow-up 1 year after ablation. Remarkably, renal outcome measures remained unchanged in long-term clinical follow-up (mean, 6 years; range, 6–108 months); there was minimal new-onset CKD or significant progression of CKD.

Our results were consistent with prior case series and further extend the durable renal outcome of thermal ablation. Collectively, the renal functional outcome after multiple RCC ablations is nearly equivalent to that of a single RCC ablation [16] and compares more favorably with the reported 14–27% decrease in estimated GFR after partial nephrectomy for multiple renal tumors [25]. This stark contrast of renal outcome is not surprising because thermal ablation and nephrectomy differ fundamentally in their technical approaches and therapeutic mechanisms. In this regard, ther-

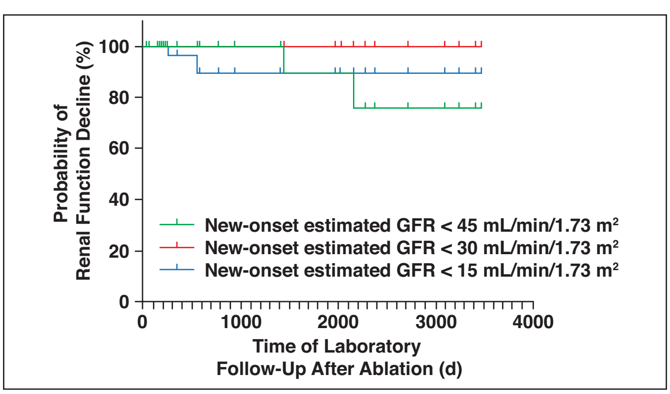


Fig. 4—Assessment of chronic kidney disease (CKD) progression after thermal ablation of multifocal renal cell carcinoma (RCC). Kaplan-Meier plot illustrates frequencies of new-onset stage-specific CKD. GFR = glomerular filtration rate. Tick marks indicate censored cases.

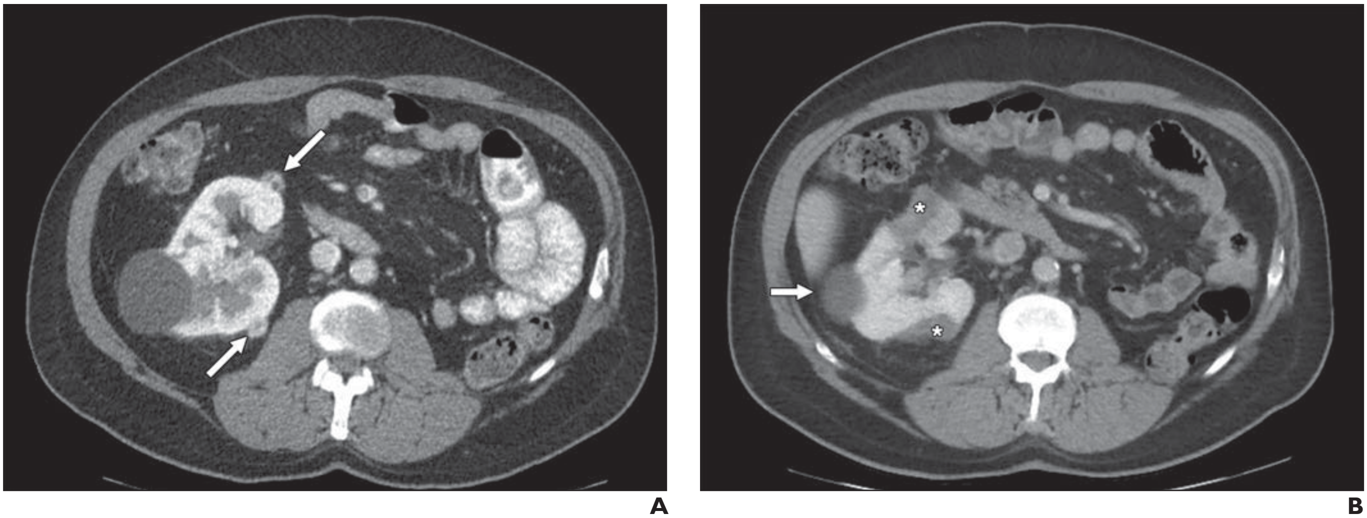


Fig. 5—67-year-old man with history of left nephrectomy for renal cell carcinoma (RCC) who presented with multifocal RCC in right kidney.
A, Axial contrast-enhanced CT scan of abdomen shows multiple right RCCs (*arrows*).
B, Axial contrast-enhanced CT scan of abdomen obtained 1 month after microwave ablation of multifocal right RCC. Asterisks indicate zones of ablation. Arrow indicates benign cyst.

mal ablation offers at least two theoretic advantages. First, thermal ablation eliminates clamping of the renal hilum, thus avoiding global renal ischemia, which is a major cause of renal decline in nephrectomy [26]. Second, thermal ablation may improve renal parenchyma preservation by in situ ablation rather than extirpative resection, where reduction of renal volume is associated with renal decline and a poor prognosis [27]. Given that maximal renal preservation is among the highest priorities when evaluating therapeutic interventions, thermal ablation should at least be considered in the multidisciplinary care for patients with multifocal disease, especially for selected patients with existing renal impairment who may otherwise be at greater risk for end-stage renal failure after invasive surgical interventions.

Despite advances in surgical techniques [3, 9, 28], surgical resection of multiple RCCs remains technically challenging, with reported complications ranging from 11% to 50% of cases [3, 8–10]. Furthermore, partial nephrectomy for patients with multiple renal masses in a single operative session inherently protracts the operation time and increases anesthesia use, which may lengthen the recovery and hospital stay and may further increase the overall postoperative complication rate [3, 8–10]. By contrast, thermal ablation uses CT guidance for precise targeting to diminish collateral damage [18]. In the current study, there were no major intraprocedural complications after thermal ablation of multifocal renal mass. Nine (18%) minor complications were encountered; all consisted of asymptomatic perinephric hematomas that resolved spontaneously with conservative management. Our relative risk analysis suggests that these complications likely reflect the complex tumor anatomy based on renal nephrometry scores. Nevertheless, this frequency of hematoma is higher than those reported for ablation of a single RCC (hematoma frequency: range, 5–10%) [23, 29]. It is reasonable that multiple probe placements required for multifocal disease likely increase the bleeding complication risk simply because of the greater number of punctures of the renal capsule. Thus, the risk of hematoma for multifocal RCC is an important consideration in treatment planning.

There was only a single occurrence of urinoma (1/49, 2%) observed after thermal ablation, in contrast to complications that are more common after nephrectomy such as urine leak, renal vascular injuries, and acute kidney injuries. In fact, adjacent nontargeted tissues such as the bowel, psoas muscle, and ureter were protected from thermal injury by

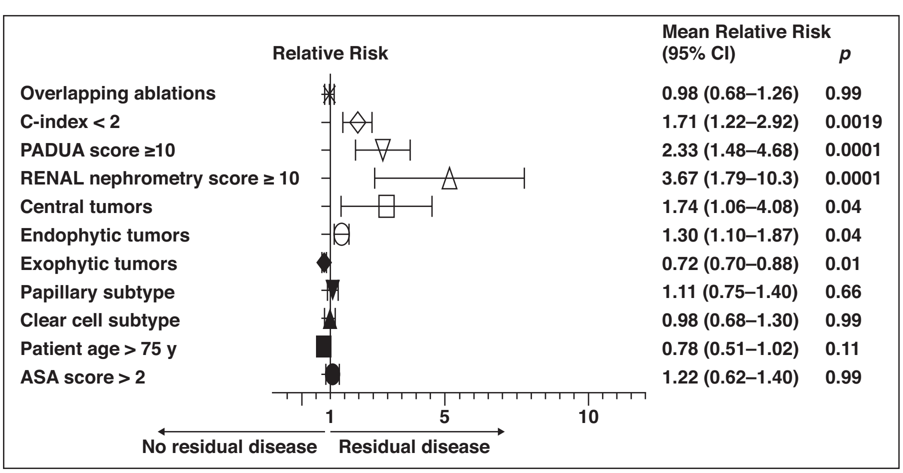


Fig. 6—Relative risk analysis to identify predictors of residual disease after thermal ablation of multifocal renal cell carcinoma (RCC). Forest plot is shown to compare outcomes of residual disease versus no residual disease on basis of individual patient, tumor, and procedural variables. Symbols represent mean of relative risk. Vertical line shows no relative risk. Whiskers show standard error. C-index = centrality index; PADUA = preoperative aspects and dimensions used for anatomical; RENAL = radius, exophytic versus endophytic properties, nearness of tumor to the collecting system or sinus, anterior versus posterior, location relative to polar lines; ASA = American Society of Anesthesiologists.

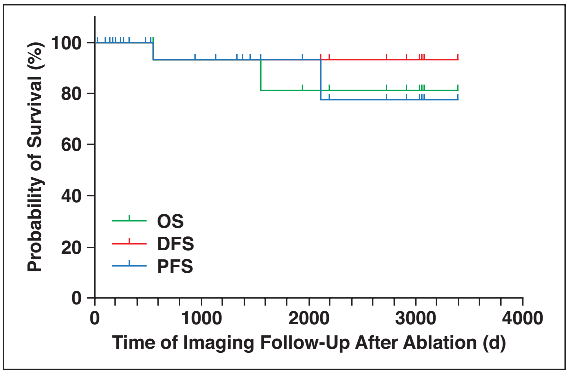


Fig. 7—Kaplan-Meier plot illustrates overall survival (OS), disease-free survival (DFS), and progression-free survival (PFS) of patients who underwent thermal ablation of multifocal renal cell carcinoma during imaging follow-up period. Tick marks indicate censored cases.

using hydrodissection in 16 of 49 (33%) and retrograde pyeloperfusion in three of 49 (6%). Patient recovery was overall excellent; all patients were discharged from the hospital on the same as or the day after ablation. These results show that thermal ablation achieved a favorable safety profile and overall low complication rate irrespective of ablative modality.

This study has several limitations. The retrospective analysis of a small cohort of patients allows selection bias and inherently limits the strength and generalizability of our results. Additionally, the small and heterogeneous patient group prohibits unbiased, multivariable statistical analyses. Notably, the disproportional use of ablation modalities presents logistic challenges for cross-comparison study. Multiinstitutional collaboration of a data registry or a clinical trial is necessary to further investigate the role of thermal ablation in a larger patient population. Thermal ablation is currently recommended only for early-stage renal masses [12], and all of our patients had RCCs smaller than 4 cm and did not have extensive disease. Until thermal ablation achieves an established role for advanced disease, nephrectomy remains the standard therapy whenever feasible. Last, direct comparison between thermal ablation and other treatment modalities was not performed. Nevertheless, our encouraging results provide impetus for prospective clinical trials to compare clinical outcomes of thermal ablation versus nephrectomy and to evaluate the merits and limitations of each approach.

Conclusion

CT-guided percutaneous thermal ablation is a safe and effective nonsurgical alternative that offers favorable long-term oncologic and functional outcomes for patients with multifocal RCC.

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