Likelihood of Incomplete Kidney Tumor Ablation with Radio Frequency Energy: Degree of Enhancement Matters

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Purpose: Larger size and clear cell histopathology are associated with worse outcomes for malignant renal tumors treated with radio frequency ablation. We hypothesize that greater tumor enhancement may be a risk factor for radio frequency ablation failure due to increased vascularity.

Materials and Methods: A retrospective review of patients who underwent radio frequency ablation for renal tumors with contrast enhanced imaging available was performed. The change in Hounsfield units (HU) of the tumor from the noncontrast phase to the contrast enhanced arterial phase was calculated. Radio frequency ablation failure rates for biopsy confirmed malignant tumors were compared using the chi-squared test. Multivariate logistic analysis was performed to assess predictive variables for radio frequency ablation failure. Disease-free survival was calculated using Kaplan-Meier analysis.

Results: A total of 99 patients with biopsy confirmed malignant renal tumors and contrast enhanced imaging were identified. The incomplete ablation rate was significantly lower for tumors with enhancement less than 60 vs 60 HU or greater (0.0% vs 14.6%, $p=0.005$). On multivariate logistic regression analysis tumor enhancement 60 HU or greater (OR 1.14, $p=0.008$) remained a significant predictor of incomplete initial ablation. The 5-year disease-free survival for size less than 3 cm was 100% vs 69.2% for size 3 cm or greater ($p<0.01$), while 5-year disease-free survival for HU change less than 60 was 100% vs 92.4% for HU change 60 or greater ($p=0.24$).

Conclusions: Biopsy confirmed malignant renal tumors, which exhibit a change in enhancement of 60 HU or greater, experience a higher rate of incomplete initial tumor ablation than tumors with enhancement less than 60 HU. Size 3 cm or greater portends worse 5-year disease-free survival after radio frequency ablation. The degree of enhancement should be considered when counseling patients before radio frequency ablation.

Key Words: ablation techniques; image enhancement; radiation; carcinoma, renal cell

Abbreviations and Acronyms

CT = computerized tomography
DFS = disease-free survival
NS = nephrometry score
RCC = renal cell carcinoma
RFA = radio frequency ablation
SRM = small renal mass

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THE incidence of small renal masses is increasing, largely due to the increased detection of incidentally discovered tumors.[1,2] As such, the surgical treatment of SRMs has shifted toward minimally invasive approaches and nephron sparing surgery.[3] Focal ablative techniques such as radio frequency ablation and cryoablation have now matured with satisfactory long-term oncologic outcomes and are accepted treatment options for patients with SRMs.[4–7]

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RFA relies on the transfer of thermal energy to destroy targeted tissue.[8,9] Uniform temperatures greater than 60C are required to cause cell death and ensure optimal ablation success.[10,11] However, all thermal ablation technologies are sensitive to a heat sink effect as areas with high blood flow may shunt heat energy away from the target tissue.[12,13] As such, the tumor being treated may not entirely reach the necessary temperature for cell death.

Previous work has demonstrated that RFA outcomes are associated with tumor diameter and tumor histology, with larger size and clear cell histopathology associated with higher rates of recurrence.[14,15] The degree of tumor enhancement has not been evaluated as a factor. Clear cell carcinomas are typically more vascular and are distinguished from other tumor types by greater enhancement on contrast imaging.[16] However, the enhancement of clear cell and other types of SRMs can vary significantly. We hypothesized that the degree of kidney tumor enhancement, as a surrogate for tumor vascularity, may be an independent risk factor for incomplete radio frequency ablation and lower 5-year disease-free survival.

METHODS

After obtaining institutional review board approval a retrospective review of patients who underwent RFA for kidney tumors at our institution from 2005 to 2014 was performed. CT with and without contrast before RFA must have been available for inclusion in the analysis. Patient demographic data and tumor characteristics were recorded. The degree of tumor enhancement (change in HU) from the noncontrast phase to the contrast enhanced arterial phase was calculated. This was performed by identifying a region of interest within the tumor at its largest dimension on the axial images and obtaining the average HU (fig. 1).

Our RFA technique has been described previously.[15] Only patients who had biopsy confirmed RCC were included in the ablation failure and DFS analysis. Incomplete ablation was defined as persistent enhancement of greater than 15 HU in the targeted area at the first 6-week followup CT. Those who underwent repeat ablation after initial ablation failure had the entire volume of the tumor ablated. DFS was defined as freedom from local recurrence. Local recurrence was considered if there was enhancement on followup imaging within the site of ablation after successful initial ablation. Patients with an initial incomplete ablation were excluded from DFS analysis. This was done to maintain a homogeneous study population as not all who had initial ablation failure underwent repeat ablation.

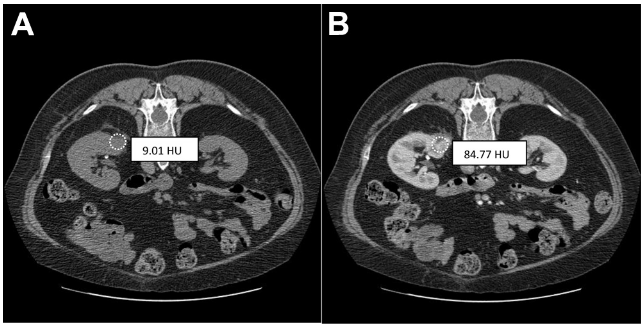

Figure 1. Measuring kidney tumor enhancement using region of interest to determine HU in noncontrast phase CT (*A*) and arterial contrast phase CT (*B*).

For statistical analysis tumor size was categorized as less than 3 cm and 3 cm or greater, tumor NS was categorized by less than 6 and 6 or greater, and degree of enhancement was categorized as less than 60 and 60 HU or greater. This stratification was selected based on mean HU change in the cohort, which was 63.8. Incomplete ablation rates between the groups were compared using the chi-squared test. Multivariate logistic analysis was performed to assess predictive variables for incomplete ablation. DFS was calculated using Kaplan-Meier analysis and compared using the log rank test. Statistical analysis was performed using STATA® v14.

RESULTS

A total of 158 patients with preoperative contrast enhanced CT were available for review. Tissue diagnosis was achieved in 81% of patients based on biopsy before ablation. Mean change in tumor enhancement of each cell type is listed in table 1. Overall 99 patients were diagnosed with RCC and were included in the ablation success and DFS analysis. Patient demographics and tumor characteristics are shown in tables 2 and 3. Overall there were 7 (7.1%) patients who had initial incomplete ablation detected on the 6-week post-ablation CT. Six of the patients underwent repeat ablation while 1 patient was observed. That patient has followup to 6 years with evidence of tumor growth to 3.7 cm but has not experienced any signs of systemic disease.

Malignant tumors with a 60 HU or greater change had a 14.6% rate of incomplete ablation compared to 0% for malignant tumors with enhancement less than 60 HU (p=0.005). Tumor size, tumor histology and NS were not predictive of incomplete ablation (table 4). On multivariate logistic regression analysis change in enhancement

Table 1. *HU change by cell type*

	Mean (SD) HU Change
Clear cell (64)	70.6 (36.3)
Papillary (20)	33.4 (21.1)
Chromophobe (2)	70.5 (0.71)
RCC not specified (13)	75.9 (30.4)
Oncocytoma (15)	75.6 (45.8)
Nondiagnostic (3)	79.7 (11.7)
Benign not specified (10)	50.6 (41.1)
No biopsy (31)	58.1 (31.7)