Planning Radiofrequency Ablation of Renal Tumors: Predicting Response from Standard Pre-Ablation MRI Scans

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Purpose:
Image-guided percutaneous RF ablation of malignant renal neoplasms is gaining acceptance among the array of promising tumor thermotherapy procedures with encouraging results from the clinical trials conducted thus far [1-7]. The rationale of ablation of malignant kidney tumors is, in contrast to many other organs, directed towards eradication of a relatively small non-metastasizing primary neoplasm aiming at complete cure. To date, the procedure has been practiced under percutaneous CT [1,2], MRI [3], and laparoscopic [5] guidance as well as under direct surgical exploration [6,7]. The extent of induced necrosis is typically evaluated on immediate post-procedural MRI or delayed CT scans. Using MRI to guide and monitor tumor ablation, such feed-back information is offered by the intra-procedural scans [1,8] thereby eliminating the need to reschedule the patient for additional sessions to address residual tumor. We aimed to further refine the technique by testing the hypothesis that the volume and enhancement criteria of malignant renal tumors, as evaluated on standard pre-ablation MRI scans, can be used to predict the course of the ablation procedure in terms of tissue impedance, current, total amount of energy and total ablation time required to achieve complete tumor necrosis.

Material and Methods:
MRI guided and monitored RF ablation procedures of 13 malignant renal neoplasms involving 11 patients (mean age = 74.3 years) were retrospectively analyzed. Patients were treated under protocols approved by our Institutional Review Board for Human Investigation. Inclusion criteria consisted of (1) peripherally located tumors; that were (2) deemed completely ablated, on intra-procedural MRI, in a single treatment session; with (3) no MRI evidence of recurrence for at least 6 months following ablation. Histologically, treated tumors included 6 clear cell carcinomas, 4 oncocytic RCCs, 1 papillary carcinoma, and 1 unclassified adenocarcinoma. The specific pathology was inconclusive in one patient due to tumor necrosis but the patient developed a contralateral clear cell carcinoma 3 years later. All pre-ablation MR scans were performed on 0.2 T open interventional MR scanner (Magnetom Open, Siemens Medical Solutions, Germany) that was subsequently used to guide and monitor the ablation procedures. Evaluated pre-ablation scans consisted of TSE T2WI (TR/TE/NSA/ETL = 4000/102/4/7) and pre and post gadolinium T1WI (TR/TE/NSA/FA = 440/15/5/90º). Gadolinium DTPA was injected manually (0.1 mmol/Kg) and post-contrast scans were acquired in the equilibrium phase approximately 3-5 minutes following gadolinium administration. Tumor volumes were calculated from their 3 dimensions (d1, d2, d3) as measured on T2WI using the ellipsoid formula [Volume = $(4\pi/3)$ (d1/2) (d2/2) (d3/2)]. The tumor-to-kidney contrast-to-noise ratios (CNR) were calculated on each of the pre and post-contrast T1WI using the formula: [(SA tumor – SA kidney)/SD noise]. Cool-Tip RF ablation was performed using a 200-watt-system (Radionics, Inc., Burlington, MA, USA) and custom fabricated 17-gauge MR-compatible electrode with a 2 or 3 cm exposed tip. During each ablation procedure, tissue impedance, RF current and power were recorded at one-minute intervals. The total amount of energy deposited during each procedure was calculated. The number of ablation cycles and RF electrode positionings were recorded as well as the total ablation time required to replace the entire tumor by the induced thermal lesion; defined as a hypointense zone detected on intermittently acquired TSE T2-weighted [TR/TE/NSA/ETL: 1856 / 105 /4/ 17, 92 second acquisition time] and/or TSE STIR [TR/TE/NSA/ETL: 2682 / 48 / 3 / 7, 2.5 minute acquisition time] images during the procedure. Pearson correlation coefficients were calculated between two tumor parameters evaluated on pre-ablation MRI (i.e. tumor volume and difference between pre and post-contrast tumor-to-kidney CNR) and four ablation performance parameters (i.e. mean impedance, mean current, total energy, and total ablation time).

Results:
The results are given in Table 1. Statistically significant correlations (α=0.05, two-tailed) were obtained between the initial tumor volume and the total amount of energy required to deem complete tumor necrosis on intra-procedural MRI, and between the difference of tumor-to-kidney CNRs on pre and post-contrast scans and the mean required RF current. The strength of these correlations was however modest, accounting for 37% of the variances observed in each case based on corresponding R-squared values. No significant correlation was noticed between the evaluated tumor parameters and either of the tissue impedance or total ablation time. The number of RF ablation cycles ranged between 2 and 6, implemented at 1- 4 electrode positions per tumor and did not depend on tumor volume or enhancement criteria. No particular histological type of renal malignancy was associated with a distinctive pattern of ablation performance parameters.

Table 1. Pearson Product Moment Correlation Coefficients (N=13)

		Tumor Volume (cc)	Net CNR
Impedance (ohms)	Pearson r (95% conf limits)	*-0.55 (-0.84, 0.01)*	*-0.54 (-0.84, 0.01)*
	Sig. (2-tailed)	*0.054*	*0.055*
Ablation Time (min)	Pearson r (95% conf limits)	0.32 (-0.28, 0.74)	-0.07 (-0.60, 0.50)
	Sig. (2-tailed)	0.288	0.812
Energy Required (kJ)	Pearson r (95% conf limits)	**0.61 (0.08, 0.87)**	0.44 (-0.15, 0.80)
	Sig. (2-tailed)	**0.028**	0.137
Current Applied (Amp)	Pearson r (95% conf limits)	*0.53 (-0.02, 0.84)*	**0.61 (0.09, 0.87)**
	Sig. (2-tailed)	*0.060*	**0.026**

* Correlation is significant at the 0.05 level (2-tailed).

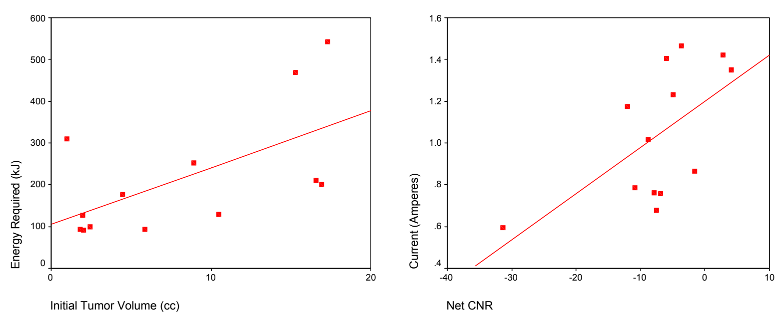

Figure 1: *scatterplots for the two statististically significant correlations. The second scatterplot, i.e. between current and CNR change, suggests that the observed correlation may be driven by a single outlier.*

Discussion:
This initial analysis demonstrated that review of current standard pre-ablation MRI scans failed to elucidate a comprehensive working ablation plan. Although a significant correlation has been demonstrated between the targeted tumor volume and the total energy required for complete treatment, core questions regarding the required total ablation time and the number of electrode insertions and ablation cycles cannot be addressed *a priori*. Pre-ablation MRI scans acquired in the same low-field environment typically utilized for MR-guided ablation procedures remain central to planning issues such as the best electrode trajectory and the ideal patient position during the procedure. These results also reinforce the value of intra-procedural MRI guidance and monitoring in providing critical online feedback information about the progress of these largely response-dependent procedures. Further analysis of a larger number of ablation procedures on various tumor cell types is required. Correlation with other pre-ablation parameters such as tumor perfusion may also worth further investigation.

References:

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