Magnetization Transfer for Early Assessment of Hepatic Tumors Treated with Thermal Ablation

A. M. Gharib[1], M. S. Kotys[2], D. M. Thomasson[2], J. K. Locklin[3], B. J. Wood[3]

[1]National Heart, Lung and Blood Institute, National Institutes of Health, Bethesda, MD, United States, [2]Laboratory of Diagnostic Radiology Research, National Institutes of Health, Bethesda, MD, United States, [3]Diagnostic Radiology Department, National Institutes of Health, Bethesda, MD, United States

Introduction:

Percutaneous and surgical thermal ablation of primary and metastatic hepatic tumors has become a common method of treating resectable and unresectable liver neoplasms. Thermal ablation with radiofrequency, laser, microwave, or cryoablation leaves a treatment zone of coagulation necrosis that is intended to geometrically envelope tumor to ensure local control. This region of coagulation necrosis commonly appears similar on conventional imaging, as an ablated zone of non-perfused, devascularized tissue at various stages of evolution into fibrosis and granulation tissue. [1] The ablated tumor is commonly indistinguishable from ablated adjacent normal liver with conventional imaging (routine PET/CT, MR, CT). Incomplete treatment of tumor results in regrowth due to lesions size, geometry, overall micro-perfusion, or nearby blood vessels greater than 3mm in size, which causes perfusion-mediated convective heat loss. [2] This can result in tumor tissue that does not reach a lethal time / temperature combination.

This insufficient treatment can often be successfully completed if it is discovered early and the physician is aware of the presence of local residual neoplastic cells. Unfortunately, local failures result if the untreated cells are left alone to grow, without repeat ablation targeted at the residual disease. Early detection and early re-ablation prevents tumor growth into a geometrical configuration that is unfavorable, as can occur if routine imaging is used for follow-up. A clinical dilemma results when post-ablation imaging findings are suspicious but not definitively diagnostic for local failure. Conventional enhanced CT and MR show the treated region, but it may be difficult to perceive prior tumor location, which complicates interpretation. Validated imaging techniques as surrogate markers for early detection of untreated tumor could improve local control, which could potentially impact outcomes in specific clinical scenarios.

Materials and Methods:

Segmented magnetization transfer (MT) sequences of the liver were performed on a Philips 3.0 Tesla (Philips Medical Systems, Best, Netherlands) using a Philips 6 element cardiac SENSE coil in two patients three days before as well as one day after radiofrequency ablation (RFA) of liver neoplasms. The MT images were collected using a TFE with TFE factor 13, TR 4.0 ms, TE 1.9 ms, and 10º flip angle. The MT pulse was applied at 1100 Hz off-resonance with an RF angle of 620 degrees. Magnetization transfer ratio (MTR) maps were calculated using Philips Viewforum MT analysis tool. Post-processing of the MTR maps was performed including region of interest (ROI) analysis in the pre-RFA tumor, post-RFA coagulation necrosis in the region of the tumor, post-RFA coagulation necrosis in the region of adjacent normal liver, and in normal liver pre and post RFA. MT-pulsed images pre and post RFA were manually registered with the Medical Image Processing and Visualization java-based software (MIPAV, Center for Information Technology, NIH, Bethesda, MD) and then fused for display with Image J software (NIH).

Results:

The MTR defined by ROIs confirmed the visual differences between tumor and normal liver pre- and post-RFA, and MTR defined the relationship of tumor to treatment zone on one un-fused post-RFA MT image. After RFA, there is apparent normalization of tumor MTR following RFA to near that of remote normal liver (comparing values from the same scan date). [Table 1] One patient's MTR did not fully normalize (16.5 % post RFA tumor vs. 19 % normal remote liver, images not shown). In this patient, the RFA time was shorter, and there were 3 large vessels adjacent to the tumor likely causing perfusion-mediated heat loss, which may have resulted in local failure. The MTR also tended to be lower in the burned liver adjacent to the treated tumor, when compared to normal remote liver. When comparing the liver MTR obtain from the same scan (i.e. same day), values of the burned normal liver adjacent to the treated tumor is markedly lower than untreated remote normal liver obtained. MTR changes corresponded with clinical and conventional radiographic impression of local failure or incomplete treatment.

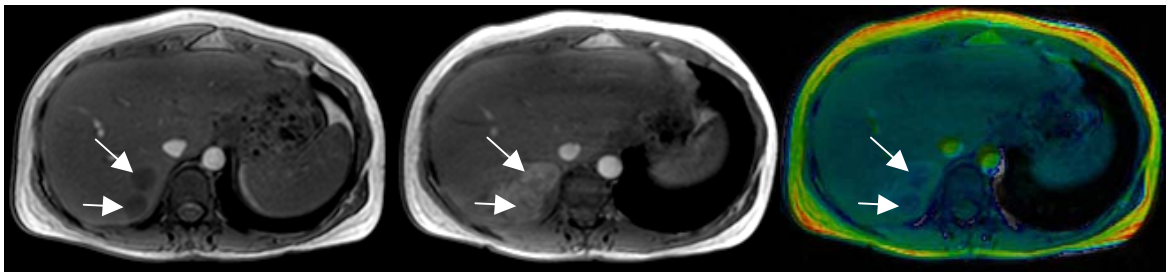

Figure 1. *MT-pulsed pre-RFA(a), post-RFA (b) and fused image (c) suggests complete treatment with thermal lesions overlapping the tumor. The architecture of the now dead tumor(arrows) can be easily discerned within the thermal lesion, differentiated from burned normal liver at the margin of the thermal lesion.*

	Pre-RFA	Post-RFA		Pre-RFA	Post-RFA
Tumor	**11.00%**	**22.10%**		**14.60%**	**16.50%**
Remote normal liver	**16.60%**	**23.10%**		**19.40%**	**19.00%**
Burned normal liver next to tumor		**16.50%**			**11.90%**

Table 1: *MT ratios in 2 patients in tumor, treated normal liver and untreated remote normal liver.*

Conclusion:

Early analysis in a limited number of patients suggests that MT could provide useful spatial information about the relationship of tumor to treatment zone, although further study is required to confirm. Additionally, there is an apparent correlation between the possible amount of heat delivered the normalization of MTR. Assuming that defining the relationship of tumor to treatment zone correlates with early detection of residual tumor post-ablation, such information could impact clinical outcomes by facilitating expeditious re-treatment before the residual tumor grows into a geometrically unfavorable configuration.

References: 1) S. Nahum Goldberg. Cancer, 88:2452-2463 (2000), 2) David S. K. Lu. AJR, 178:47-51 (2002)