Paramagnetic liposomes as thermosensitive probes for MRI guided thermal ablation. Experience with laser and radiofrequency ablation in rabbit liver in an interventional 0.5 Tesla MRI system

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Introduction:

Temperature sensitive liposomal MRI contrast agents constitute a novel approach for thermal dosimetry during MRI guided thermal ablation procedures. Below the phase transition temperature (Tm) of the liposome membrane, the T1 relaxation enhancement of the liposomal agent is exchange limited and the effects on the MR signal are minimal. As the temperature approaches Tm, the transmembrane water exchange kinetics is faster and the T1-relaxivity increases rapidly and markedly before leveling off as Tm is exceeded (1, 2). In this study, the feasibility of using thermosensitive liposomes for thermal imaging in conjunction with MRI guided laser- and radiofrequency ablation of liver was examined.

Materials and methods:

Laser- and radiofrequency ablation was performed in eight rabbit livers in-vivo in a 0,5 T vertically open whole body MR system. One lesion (lesion A) was made in each of the rabbit livers without contrast enhancement. A temperature-sensitive contrast agent based on liposome encapsulated gadolinium with a transition temperature of 57˚C was injected intravenously after cooling of the tissue, and two additional lesions (B and C) were made. T1-weighted scans were performed during heating and after tissue temperature had normalized for all lesions. The imaging parameters were TR = 300 ms, TE = 19 ms, FA = 90˚, slice thickness 4 mm, spacing 4.5 mm, 256 x 256 acquisition matrix and four signal averages.

Results:

Lesions made prior to contrast injection showed decreased signal intensity (SI) compared to baseline during heating and a slight increase after normalization of tissue temperature in both the laser group (ΔSI = 12.1%, SD=2.3) and the radiofrequency group (ΔSI = 9.1%, SD = 7.9). For lesions made after administration of the contrast media, a delayed and non-reversible effect was observed where the signal intensity of treated areas was significantly increased after normalization of the tissue temperature in both the laser ablation group (ΔSI = 34.5%, SD=11.9) and the radiofrequency group (ΔSI = 26.3%, SD = 10.9). See figures 1 and 2. The increased signal intensity was present on T1-weighted scans more than 60 minutes after the thermal treatment.

Discussion:

The immediate increased T1-relaxivty associated with heating above the phase transition temperature measured in-vitro was not prominent in this in-vivo model. However, a delayed and non-reversible effect was observed where ΔSI of treated tissue was further increased after normalization of the tissue temperature. The reason for this non-reversible effect is not fully established, but may be caused by leakage of GdDTPA-BMA from the liposomes into the surrounding tissue at temperatures above Tm and subsequent entrapment of the contrast media due to coagulation of vessels.

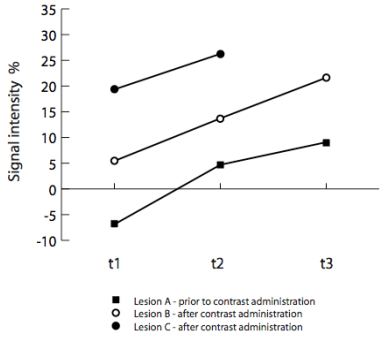

Figure 1. Mean relative signal intensity of lesions during and after radiofrequency ablation of four rabbit livers. Relative time is indicated on the horizontal axis; during heating t1, after the tissue temperature is normalized t2, and fifteen to twenty minutes after normalized tissue temperature t3.

Conclusion:

The persistent signal enhancement found in areas exposed to a temperature above the threshold temperature allows thermal monitoring of MRI guided thermal ablation procedures, such as radiofrequency ablation, where other MRI based thermometry methods cannot be used. Presumably, thermal monitoring would be of particular interest when treating large tumors requiring multiple placements of the energy applicator or tumors near large vessels where repositioning of the energy applicator can be necessary due to the uneven distribution of the thermal energy.

References:

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2. Il´yasov, K., et al. *Paramagnetic liposomes as thermosensitive probes for MRI-guided thermal ablation: feasibility study on the perfused porcine kidney*. *ISMRM*. 2001. Glasgow.

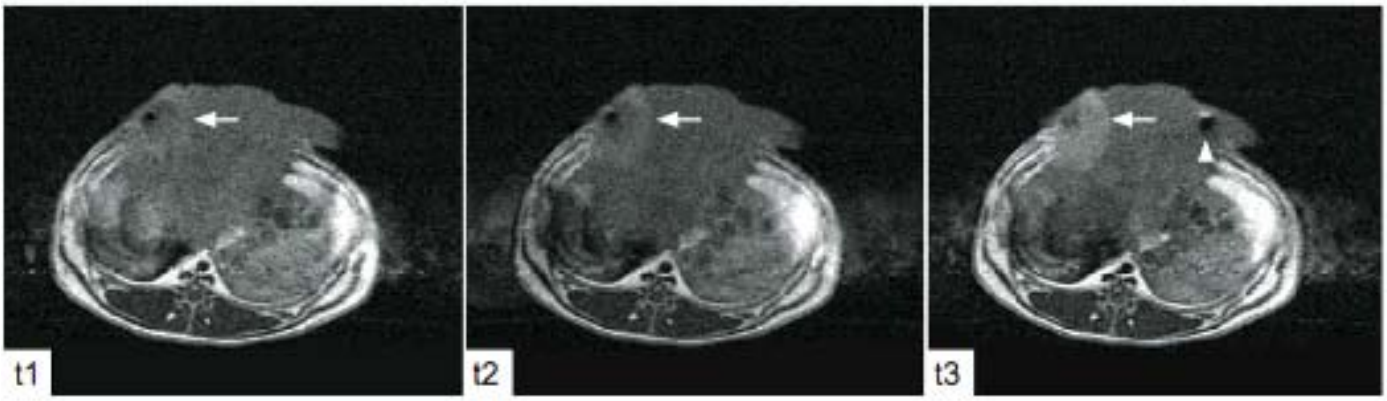

Figure 2. T1-weighted images of radiofrequency ablation in rabbit liver after injection of liposomal contrast during heating (t1), after normalization of tissue temperature (t2) and 15-20 minutes after normalization of tissue temperature (t3). Note increasing signal intensity in the periphery of the thermal lesion in the right medial liver lobe (white arrows). The radiofrequency electrode have been repositioned to the left lateral liver lobe at t3 (white arrowhead).