Combined use of MR-HIFU and intra-arterial embolization to reduce heat sink: quantification in a porcine liver model

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Purpose MR-guided high intensity focused ultrasound (MR-HIFU) is a promising technique for image guided, non-invasive tumor ablation. One challenge for MR-HIFU of liver tumors is the high perfusion rate in the liver, which very efficiently removes heat from liver tissue. To overcome this challenge, several authors have proposed the combined use of intra-arterial embolization and HIFU ablation. The embolization will reduce the perfusion in the area of the tumor, which potentially renders the HIFU ablation more effective. However, embolization has only been used in combination with ultrasound guided HIFU (i.e. without temperature measurements). For this reason, the magnitude of this synergistic effect has never been experimentally quantified. In this study, we used proton resonance frequency shift (PRFS) temperature mapping to quantify the role of perfusion on temperature development during MR-HIFU ablation in a porcine liver model.

Materials and methods After approval by our institution´s animal experimental committee, general anesthesia was induced in one Dalland land pig and an intra-arterial catheter was positioned in the proper hepatic artery under fluoroscopy guidance. The animal was then position on a clinical 1.5-T MR-HIFU therapy system (Sonalleve, Philips Healthcare, Vantaa, Finland). A T2-weighted 3D TSE scan and T1-weighted high resolution FFE scan were made for treatment planning. Six volumetric treatment cells (4 mm diameter each) were planned in the middle liver lobe. Medium-high (200 – 300 W) acoustical powers were used in order to heat (<55ºC) but not necrotize, since this would change the attenuation properties of the tissue. After sonication of these cells, polyvinyl alcohol (PVA) particles were injected through the intra-arterial catheter and a dynamic contrast-enhanced scan was made to confirm complete shutdown of the liver perfusion. Subsequently, the six treatment cells were re-sonicated. Temperature development on the PRFS temperature maps was analyzed.

Results The peak temperature elevation after embolization was significantly higher than the peak temperature elevation in the perfused liver ($p = 0.01$, mean ± Sd: 22.6 ± 5.3 vs. 13.7 ± 3.5 °C). The mean ratio between peak temperature elevation before and after embolization was 1.74 ± 0.55. PRFS thermometry images of ablation after embolization showed a clear concentric diffusion of heat from the focal point, as opposed to thermometry images in the perfused liver.

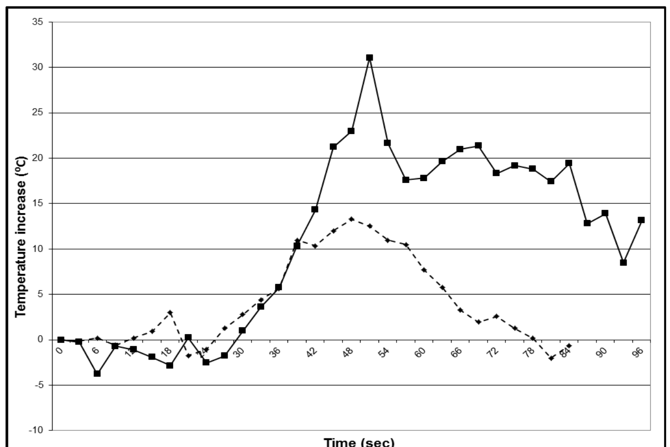

Figure: evolution of temperature increase for one treatment cell. Dotted line: perfused liver. Solid line: embolized liver.

Discussion Our results confirm the expected synergistic effect of intra-arterial embolization and HIFU. Peak temperatures were on average 1.7 times higher. This indicates that the combined use of intra-arterial embolization and MR-HIFU allows for ablation of larger tissue volumes with similar acoustical power and within the same time frame. In addition, embolization is known to be an effective anti-cancer therapy in itself, specifically in the (highly perfused) outer rim of the tumor. Combination treatment with these minimally invasive and non-invasive treatment modalities could be an attractive treatment option for liver cancer patients in the palliative phase.

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