A combined interventional high-resolution targeted ablation, thermometry and imaging probe

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Audience: MR Interventionalists interested in high-resolution MRI-guided RF ablation and thermal monitoring.

Purpose. Conventional MRI-guided thermal or radiofrequency (RF) ablation requires a dedicated ablation catheter for delivering the energy while monitoring the thermal dose with a separate MRI detector and low resolution thermometry. Here, we demonstrate a single 3T interventional loopless antenna[1,2] that integrates all the functions of: (a) precision delivery of the RF energy; (b) high-resolution thermal mapping for monitoring of the treatment zone; and (c) quantitative T_1/T_2 imaging to confirm the extent of the ablation, *in vitro* and *in vivo*.

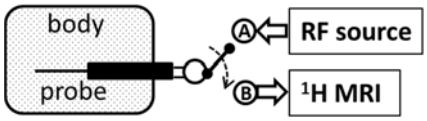

Fig 1: Schematic of a device switch-able between RF ablation & MRI

Methods. Experiments were conducted on a 3T Philips *Achieva*, using 2.2 or 0.8mm diameter λ/4 loopless antennae[1] in bovine tissue and pig aorta specimens immersed in a 3.5g/l saline bath, and *in vivo* in a rabbit aorta and thigh. A non-magnetic RF switch was used to connect the loopless antenna to the MRI receiver during MRI, or to an RF power amplifier during RF ablation (Fig. 1). For ablation, RF energy (110MHz, 30-60W) was applied for 2-6min. MRI (gradient, GRE, or turbo spin-echo, TSE; "MIX" IR-TSE T_1/T_2 mapping[3]) and MR thermometry (8s temporal resolution; proton resonance frequency-PRF shift method; 2D GRE MRI) was performed pre- and post-ablation with the antenna switched to the scanner.

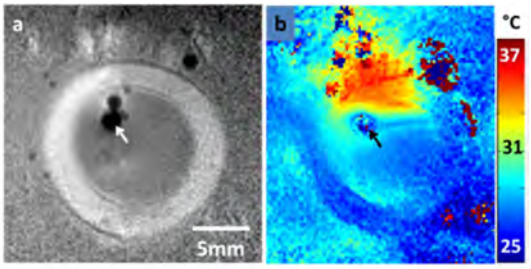

Fig 2: (a) MRI of porcine aorta (4-slice 3D TSE; resolution=0.15x0.15x2mm^3 in 170s). (b) PRF thermal image (0.25x0.25x6 mm^3 in 8s; pre-ablation temp.=25°C; arrows=probe location).

Results. Bovine tissue ablation with temperature increases ΔT>30°C by MR thermometry appeared hypo-intense on MRI. Pre-ablation MRI of an aorta specimen at 150μm resolution (Fig.2a) reveals a well-defined vessel wall. MRI thermometry at 250μm shows delivery of a ΔT=12°C thermal dose near the probe (red; Fig. 2b). Post-ablation T_1 and T_2 maps of bovine tissue reveal up to ~2-fold decreases in T_1 and ~2-fold increases in T_2, in ablated areas (Fig. 3a,b) vs. pre-ablation. *In vivo*, Fig. 3(c) shows the probe in muscle pre-ablation, Fig 3(d) shows MRI thermometry with a ΔT>50°C thermal dose next to the probe, with the ablation confirmed post-MRI in Fig. 3(e).

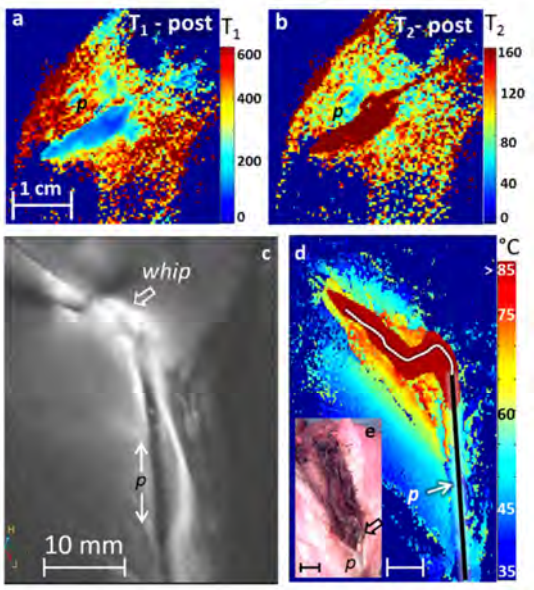

Fig. 3: Post-ablation T_1 (a) and T_2 (b) maps of bovine tissue (MIX sequence: TR/TE/TI=948/22/300ms, 0.3x0.3x2mm^3 voxels in 212s). (c) *In vivo* MRI in a rabbit thigh (*p*=antenna; MIX TR/TE/TI =649/21/300ms, FA 90°, 0.3x0.3x4mm^3 voxels in 160s). (d) MRI thermometry during ablation (red =ΔT>85°C vs 35°C pre-ablation; PRF 2D GRE, TR/TE=42/25ms, FA=25°; 0.3x0.3x8 mm^{3}voxels in 6s; probe location *p* annotated). (e) Post-mortem photo of ablation necrosis. Scale bar 1cm.

Discussion. The loopless antenna can be configured for both high-resolution MRI at 3T, and for locally ablating tissue. This permits precision localization of therapeutic targets, titration of the therapy via thermal monitoring, and assessing the immediate outcome post-ablation. MRI excitation can also be done using the probe for adiabatic excitation[4] or spatially-selective B_1-insensitive pulses[5], whereupon high-resolution MR thermometry could monitor device safety during procedures. A *single* device deployed in this way avoids size-limitations, device-coupling and safety issues associated with multiple conductor probes, potentially providing a minimally invasive vehicle for targeting, delivering and monitoring localized ablation therapy.

***References*: (1)** Ocali O et al. Magn Reson Med 1997; 37: 112-118. **(2)** El-Sharkawy AM et al, Med. Phys. 2008; 35:1995-2006. **(3)** In den Kleef, JJE et al. Magn Reson Med 1987;5(6):513-524; (**4**) Sathyanarayana S et al, JACC Card Im. 2010; 3:1158-1165. **(5)** Erturk MA et al. Magn Reson Med 2014; 72: 220-226. *Support: NIH R01 EB007829.*

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