MR-thermometry with a flexible micro-coil detector during a Nd:YAG laser ablation on a gel-phantom

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Introduction High SNR imaging with internal coil detectors has been verified and numerous designs have been proposed. Prior work employing them has shown improvements in controlling MR-guided high intensity focused ultrasound and RF ablations [1,2]. Here we present results from a phantom-experiment conducted in a 3 T GE scanner to investigate the merits of substituting the 8-channel array coil -typically used during Nd:YAG laser liver interstitial thermal therapies (LITTs)- with a flexible micro-coil[3] integrated on a commercially available laser ablation catheter.

Methods A thin-film micro-coil (copper-clad Kapton, 60 mm x 4.2 mm), tuned and matched for 3 T, with a loaded Q of 25, was integrated with a Somatex Power-Laser-Set applicator (Fig.1a). Active detuning was implemented by means of 6 cm long sub-miniature coax cable between the matching capacitor and a non-magnetic pin diode (MA4P7464F-1072). A cylindrical structure made of Perspex slices containing agar gel with 8 % india ink served as ablation phantom to ensure a cylindrical heating profile. Clear agar gel (0% ink) around the cylindrical structure was used to simulate body loading (see Fig. 1b). Two axial slices of the heated area were simultaneously monitored (TR = 7.976 ms, TE = 3.872 ms, FA = 20^0, temporal resolution = 6 s, voxel size = 0.47 mm x 0.47 mm x 10 mm, FOV = 120 mm, BW = 244.141 Hz/pixel) with the micro-coil as receiver until cooling down. A 20 mm active tip fiber operated at 25 W during ablation. Fluoro-optic sensors (Luxtron FOT lab kit) immersed perpendicularly to the axis of the probe (see Fig. 1b) were recording the temperature at d = 5 mm (L_1) and d = 10 mm (L_2) to the probe respectively in each slice (Figs. 2a and b). The heating test was repeated with the array coil used for signal reception, at 70 mm distance to the heat source. The phase images were post-processed in Matlab™ to extract the temperatures spatiotemporally using the proton resonance frequency method[4] (α = -0.01 ppm / ^{0}C). A non-heated 10 x 30 pixel ROI was used to correct for non-temperature related phase changes. The MR-derived temperatures from a 2 x 2 ROI below each sensor were compared with their corresponding point-temperature readings. The SNR maps were calculated for both coils using a 4 x 15 ROI for the estimation of the noise.

Results The magnitude and phase baseline images obtained with the micro-coil and corresponding to the fluoro-optic sensor at 5 mm (L_1) are shown in Figs. 2c and d while the SNR map of that slice is shown in Fig. 2e. The radial SNR variation for both coils, plotted along the 70 mm horizontal line centered in the middle of the axial slice (Fig. 2e), is shown in Fig.3a. The SNR of the array coil is almost constant and equal to 35. The micro-coil SNR drops as 1/r symmetrically away from the conductors. At 5 mm, the SNR of the micro-coil is 10 times higher and remains 1.5 times higher up to 15 mm distances (Fig.3a). The temperature standard deviation (STD)[5] is less than 0.5 ^{0}C up to 20 mm and less than 3 ^{0}C up to 30 mm radially away from the coil conductors (Fig.3b). The MR-inferred transient temperatures versus the fluoro-optic readings are shown in Figs.4a and b for the micro-coil and the array coil respectively. In the array coil heating experiment the applicator was displaced to the left by 10 mm leading to the shifting of the heating zone to the left (see Fig. 2b) and hence to the recording of lower temperatures by sensor L_1 (at 5 mm, see Fig. 2b) compared to sensor L_2 at 10 mm.

Conclusions The feasibility of integrating a micro-coil with a laser applicator and carrying out MR-thermometry of a gel phantom heated with Nd:YAG laser has been successfully demonstrated, probably for the first time. The micro-coil can be used with existing commercially available applicators and it does not affect the symmetry of the heating profile. The temperature prediction based on phase images can significantly improve the control during LITTs up to 15 mm distances from the coil conductors due to the excellent SNR of the micro-coil within a radius of 10-15 mm. The accurate MR-thermometry and the confirmation of the correct insertion of the laser applicator in the target (tumor) achieved with the use of the micro-coil imply a promising overall improvement of the control of LITTs. Further experiments will be conducted on excised porcine liver.

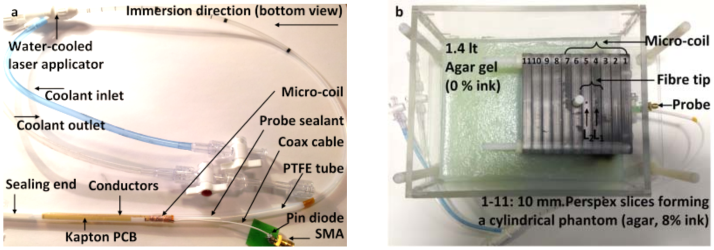

Fig.1: a) Micro-coil integrated with a laser applicator, b) ablation set up.

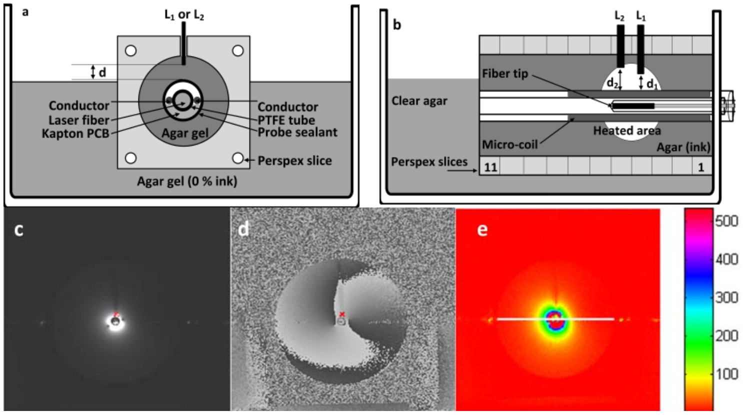

Fig.2: a) Axial view of the thermometry slices, b) sagittal view of the set up centered at the probe, c) phase, d) magnitude baseline images of the slice containing L_1 (micro-coil) and e) corresponding SNR map.

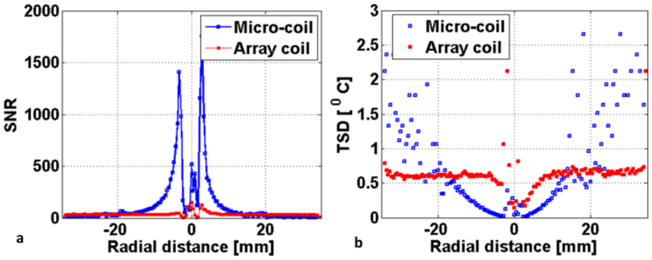

Fig. 3: a) SNR versus radius, b) temperature standard deviation

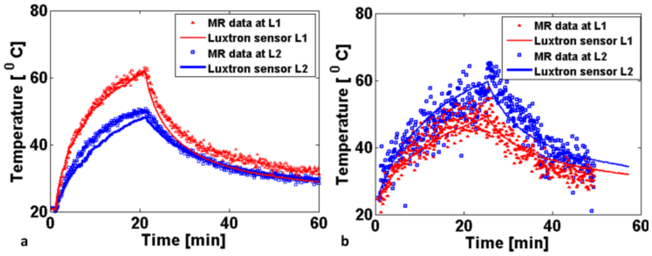

Fig. 4: MR-temperatures with a) the micro-coil and b) the array coil

References

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