MR-thermometry controlled bipolar RF tissue ablation

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Introduction

Radio-frequency (RF) ablation techniques are widely used for liver tumor treatment. It has mostly been performed using monopolar RF systems under CT or US guidance instead of MR, due to a simpler procedure and RF-MR incompatibility. Only lesions with difficult access or visibility under CT/US are currently treated under MR guidance. However MR imaging is performed before and after treatment for probe positioning and control, but not during the treatment. More than simple guidance, simultaneous MR imaging is of great interest for MR-thermometry lesion monitoring during ablation. To overcome the RF-MR incompatibility techniques like intermittent switching (which is not properly simultaneous) [1], and RF filtering [2,3] have been developed. In this study we present the feasibility of MRI temperature control of RF lesion in an ex-vivo porcine liver model, using an new, mono-probe bipolar ablation system, with appropriate filtering.

Methods

MR imaging and RF ablation were performed on a 1.5T Intera MR system (Philips Medical Systems, Best, NL) using a CelonLab Power (Celon AG, Berlin, D) RF generator placed outside the MR room, and a bipolar CelonProSurge electrode. Up to 3 such electrodes can be used with this system according to the desired power output and lesion size. The RF filter was designed by Image Guided Therapy SA to remove RF perturbations induced by the generator. Typical bipolar RF protocol was applied (20W output power during 7 minutes), with probe internal cooling. MR imaging parameters were: 2D FFE sequence, surface coil (12 cm diameter), water selective excitation, EPI factor 5, TR/TE 260/15 ms, 3 x 5 mm slices, 85x96 acquisition matrix, 18 cm FOV. Temperature maps were calculated by proton resonance frequency (PRF) from the phase images with Thermoguide software (IGT SA, Pessac, F) on a separate workstation.

Results

Figure 1 presents MR temperature images and corresponding necrosis maps [4] (superimposed to anatomical view) obtained after 5 minutes of RF application. Color code correspond to temperature increases of +5°C (blue), +15°C (green) and +20°C (red) respectively. Images with no noticeable artifacts were obtained, allowing temperature monitoring with excellent accuracy (≤ 2°C). Figure 2 shows temperature evolution in a single pixel, located 9 mm away from the RF needle. Continuous temperature increase is observed during RF deposition, and abrupt T° drop can be observed corresponding to rapid tissue impedance increase due to desiccation and leading to artifacted images. Slow temperature decrease due to heat diffusion can be observed after RF was switched off.

Discussion

Feasibility of RF ablation with simultaneous MR imaging and temperature control has been shown, without any modification of the RF generator. The methodology presented here shows important potential for better control of RF tissue ablation, and opens possibilities for optimizing the efficiency of hyperthermia treatment protocols for wide range of RF ablation systems.

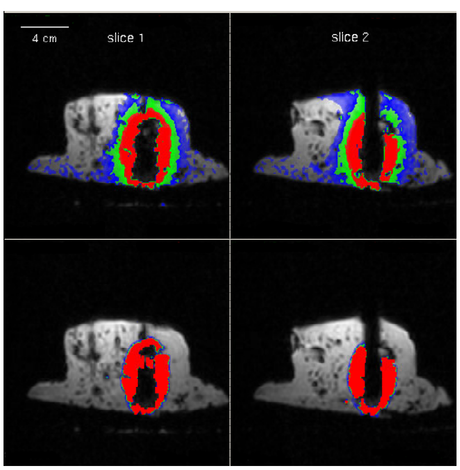

Figure1: MR images obtained with simultaneous RF ablation with temperature map (top) and thermal dose (bottom). Top images: temperature increase corresponds to +5°C (blue), +10°C (green) and +15°C (red) respectively. Bottom: pixels colored in red have reached lethal thermal dose.

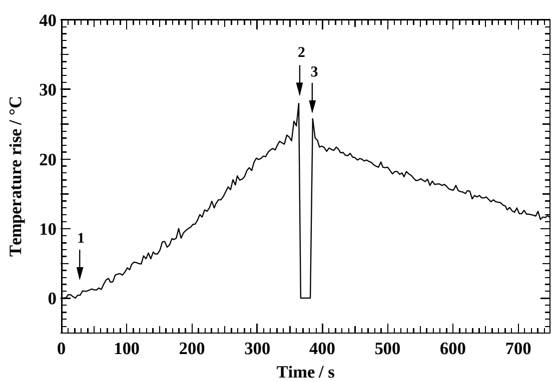

Figure2: Temperature-time profile in a pixel 9 mm away from the RF probe. Continuous temperature increase during RF deposition, abrupt T° drop corresponding to rapid tissue impedance increase, and slow temperature decrease due to heat diffusion after RF was switched off can be observed. 1) Heating start, 2) tissue impedance increase and 3) output power reset to zero.

References:
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