MR targeting guidance and MR thermometry for radiofrequency ablation in patients with liver tumours on an interventional 1.5T platform

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Introduction

The principles of RF ablation monitoring with MR thermometry are well-established for *ex vivo* and animal studies at 1.5 T. The implementation of simultaneous MR thermometry at 1.5 T for monitoring of *clinical* RF ablation remains rare due to technical challenges such as RF interference artefacts, susceptibility artefacts of RF electrodes, and inter- and intra-scan respiratory motion artefacts. The purpose of this study is to demonstrate the feasibility of MR real time targeting guidance and real time temperature monitoring for RF ablation treatment of patient liver tumours in a closed bore 1.5 T MR system.

Material and Methods

Eight patients with 15 malignant hepatic nodules not visible by US or CT (long axis diameter 0.7-2.1 cm) underwent a total of 10 RF procedures in an interventional 1.5 T MR system (Espree, Siemens, Germany). Informed consent was obtained from the patients prior to the procedure. For each of the RF procedures, one bipolar internally-cooled MR-compatible RF electrode (Celon ProSurge MR, Celon AG, Germany) with a length of 15 cm, a diameter of 0.18 cm (15.5 G), and an active zone length of 3 cm was used. After planning the trajectory on T1-weighted 3D acquisitions (Fig. 1a and 1c), the interventional radiologist placed and followed the advancement of the RF electrode into the patient's liver by alternating the imaging slice between para-sagittal and para-transverse orientations (Fig. 1b and 1d) with a balanced SSFP ("TrueFISP") interleaved radial acquisition (IRTTT, Siemens). Image parameters included: base resolution 128, 64 lines (views), TR = 4.3 ms, TE = 2.2 ms, sliding window width = 5, update rate = 275 ms. A combination stop-band filters providing an attenuation of -95 ± 5 dB was used in the transmission line of the RF generator (CelonPOWER) to avoid RF interferences artefacts. Then, the RF energy was delivered with MR compatible RF generator, placed outside the Faraday cage, at instantaneous power settings ranging from 15 to 50 W over times ranging from 10 to 30 minutes. The power was delivered and cut-off decided by resistance-controlled application of power mode (RCAP).

The MR thermometry imaging was performed simultaneously with the RF ablation using a segmented gradient echo-echo planar imaging (GRE-EPI) sequence with pressure-sensor respiratory triggering. Image parameters included: echo train length of 13, binomial water selective RF pulses, TR = 50 ms, TE = 20 ms, flip angle = 25°, BW = 1000 Hz/pixel, matrix = 128 x 128, FOV of 300 x 300 mm^2, in-plane spatial resolution of 2.3 x 2.3 mm^2, 3 slices, and slice thickness of 6 mm. Each image was transferred in real-time to a satellite PC station for post-processing. After B0 drift correction and by assuming a baseline body temperature of 37.5°C, absolute temperature measurements were obtained with the proton resonance frequency shift method (1) and were used for thermal dose calculations (2). MR imaging follow-up was performed immediately after the procedure, at 24 hours, 1 month and 3 months.

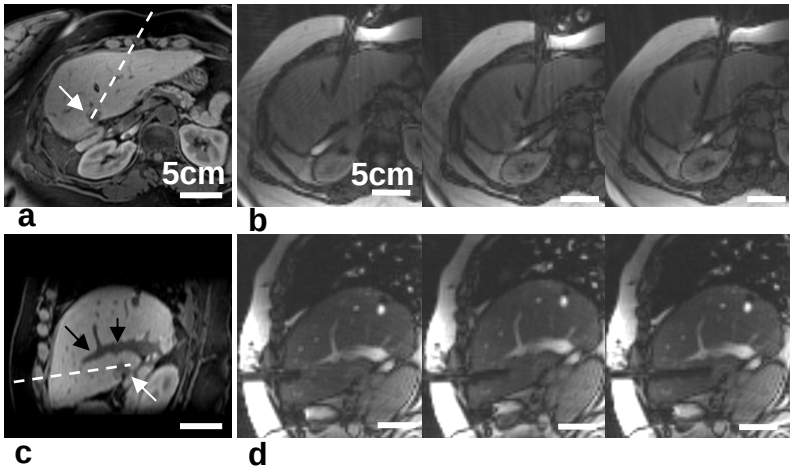

Figure 1. Example of planning and targeting of a liver tumour with MRI: a) para-transverse plane including the desired entry point and the tumour (White arrows); c) para-sagittal plane (perpendicular to the para-transverse plane) including also the entry point and the tumour. The intersection of the two planes is the planned trajectory, indicated by the dotted white line. The RF electrode advancement is followed by interactively alternating between para-transverse (b) and para-sagittal (d) orientations and updating the positions of these planes. T1 (b) and T2 (d) weighting interactive acquisition were used to insure visibility of large vessels (Black arrows) along trajectory of RF electrode and avoid damage of critical organs as gall bladder.

Results

The bipolar electrodes were adequately positioned in all cases and the targeting time was 22 ± 10 min. The image quality obtained with the respiratory-triggered GRE-EPI sequence with an echo train length of 13 indicates that *intra-scan* motion is minimized as a result of the short acquisition time (0.6s/image), and of ensuring that the acquisition of three slices takes place in the expiration phase of the respiratory cycle. During RF application, the image SNR (23-67) was preserved and the temperature accuracy was 1.6 °C in a non-heated ROI within the liver. Temperature and thermal dose maps (long axis diameter; 3.4 ± 0.7 cm) were obtained and displayed in real-time (Fig. 2). At follow-up (2-11 months), complete ablation was achieved in 14 of 15 (93%) nodules and no complication was observed.

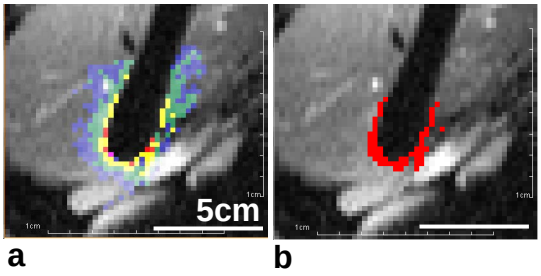

Figure 2. Final temperature (a) and thermal dose (b) maps resulting from a dynamic series of respiratory-triggered rapid GRE-EPI acquisitions are indicated. The temperature colour code levels are: blue: 39 to 42 °C; green: 42 to 47 °C; yellow: 47 to 57 °C, red: 57 to 67 °C, violet: 67 °C and above, and the pixels that have reached at least one thermal dose are indicated in red.

Conclusion

The placement of the RF electrode under interactive MR guidance is more rapid than under non-interactive MR or CT guidance. The feasibility of MR-guided and monitored RF ablation of patient liver tumours at 1.5 T, with rapid and successful RF electrode placement under interactive MR guidance and generation of temperature and thermal-dose maps in real-time using MR thermometry was demonstrated. RF ablation of liver tumours under MR guidance in a 1.5 T MR system is safe and feasible and thermal mapping may provide clinical monitoring of heat deposition during RF ablation.

References

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