In vivo Porcine Liver Radiofrequency (RF) Ablation with Simultaneous Temperature Monitoring

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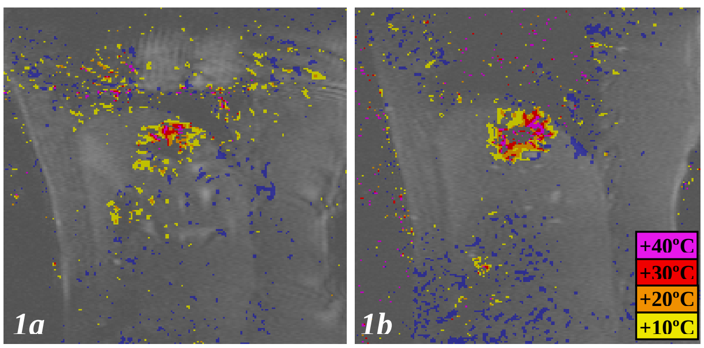
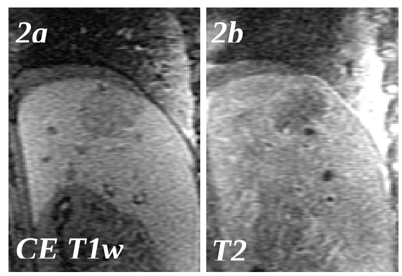
Introduction

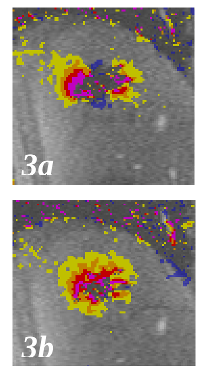
Recently, a modified commercial radio-frequency (RF) generator was described [1] which, along with an MR compatible Inconel RF probe [2], allows MR imaging and temperature mapping concurrent with RF ablation, without interruption of the treatment RF current during imaging. Here, we describe its use for ablating 3 porcine livers *in vivo*. Post ablation imaging demonstrates the achievable size of the lesion.

Methods

Magnetic resonance imaging and radio-frequency (RF) ablation tests were performed on a 0.5T interventional MR system (Signa SP, GEMS, Milwaukee WI). MR imaging was performed with a 2D gradient-echo sequence (TR/TE/BW = 60ms/30ms/±8.93kHz) with temperature maps for 64 time frames calculated by the proton resonance frequency (PRF) method and displayed in real-time on an offline workstation. Images were acquired in a single sagittal plane, placed approximately transverse to the RF electrode. The modified radio-frequency generator (RF3000, Boston Scientific Corporation, San Jose CA)[1] was placed outside the room. An umbrella-shaped needle electrode (LeVeen, Boston Scientific Corporation, San Jose CA) was attached to the output of the filter/isolation network inside the magnet room, and inserted percutaneously into the porcine liver. The pigs were anesthetized with atropine and telazol and maintained on isoflurane. One ablation was performed while the animal was manually ventilated to simulate variable respiratory motion, and images were reconstructed with a triggered, navigated, multi-baseline method [3], to simulate performing the procedure with only local anesthesia[4]. The second ablation in each animal was performed with repeatable mechanical ventilation, to represent performing the procedure under general anesthesia. Imaging for this case was performed with a simple respiratory-triggered sequence, but with 8 acquired baseline images that can be averaged for improved SNR.







Results

Temperature maps are shown for the case of variable respiratory motion with the triggered, navigated, multi-baseline reconstruction (Fig. 1a); and with mechanical ventilation and respiratory-triggered imaging (Fig. 1b). (An asymmetric heating area was noted in the ablation of Fig. 1a caused by the presence of blood vessels near the RF probe). No noticeable RF interference was observed in the MR images. The shaft of the Inconel RF electrode [2] showed signal loss due to susceptibility effects near the probe. The last ten time frames as heat was applied were evaluated for asymmetry of the heating spot and consistency in area of the +10°C contour from time frame to time frame. Gross asymmetry was evaluated by comparing how far the center of the heating spot differed from the center of the probe; values ranged from 0.1±2.1 mm (little asymmetry) to 5.4±1.5 mm (high asymmetry). Heating spot areas averaged over the 10 time frames ranged from 7.7±1.2cm^2 for the smallest ablation size to 11.4±0.6cm^2 for the largest. The standard deviation of the heating spot area ranged from 0.6cm^2 to 1.5cm^2 over the ten time frames; more inconsistency was noticed when simulated variable breathing was used, compared with repeatable mechanical respiration. Post ablation T2-weighted and post-contrast T1-weighted images were acquired in the plane of the acquired temperature maps, and demonstrated the extent of the lesion (Fig. 2). The liver was sectioned post mortem, and a qualitative examination showed regions of complete necrosis with maximum diameters from 2.5” to 3.5”. In some locations, nearby large blood vessels limited necrosis to small tissue volumes immediately adjacent to the electrode array tips.

In several time frames of two ablation procedures (Fig. 3a), artifacts in the temperature maps appeared; they were similar to the field perturbation caused by a spheroid object with a susceptibility different from tissue[5], and were likely caused by gas bubble formation. These lasted for 105 and 225 seconds, respectively, but in both cases the temperature maps eventually returned to a regular appearance (Fig. 3b).

Discussion

A modified radiofrequency (RF) generator was used to generate lesions in the livers of 3 pigs. RF generator interference in the MR images was not observed. PRF temperature maps showed the extent of heating, and post-ablation images demonstrated the extent of potential tissue destruction. Asymmetry of the heating spot was sometimes noted; it can be caused by presence of nearby blood vessels, or the relative orientation of the imaging plane with respect to the RF electrode. Noticeable temperature map artifacts caused by gas bubbles in several time frames of two ablations disappeared as heating progressed. In the future, this might be avoided with adjustment of the heating protocol.

References

[1] Vigen K, *et al.*, *Proc. 11th ISMRM*, 685 (2003). [2] Daniel BL *et al.*, *Radiology*, **205(P)**: 1555 (1997). [3] Vigen K, *et al.*. *Magn. Reson. Med.*, **50:** 1003 (2003). [4] Vogl TL, *et al.*, *Radiology*, **209:** 381 (1998). [5] Schenck JF, *Medical Physics*, **23**: 815 (1996).