Monopolar Radiofrequency thermo ablation under real-time MR temperature imaging

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Introduction

Real-time MRI monitoring of temperature evolution during Radiofrequency (RF) thermoablation is of great interest to predict the efficiency of liver tumor treatment. However, artifacts observed on MR images due to RF energy deposition generally hamper the quality of temperature maps. This problem can be overcome by the use of efficient filters in the RF transmission line [1, 2]. This study presents the technical feasibility of such a filtering device for a commercially available 100W generator with monopolar internally cooled electrode.

Methods

MR temperature imaging was performed on a 1.5T Intera magnet (Philips Medical Systems, Best, NL) using the Proton Resonance Frequency [3] technique. A 12 cm diameter surface coil was positioned on the top of the liver for MR signal detection. A multislice 2D transverse segmented EPI imaging sequence was repeated 200 times, with following parameters: 18 cm square FOV, 3 slices of 5 mm (2mm gap), 15/260 ms TE/TR, 96x85 Matrix reconstructed 128x128, 40° FA selective water excitation, EPI factor 5. The MR compatible RF needle (Radionics cool-tip, Tyco healthcare, Burlington MA, USA) was inserted vertically in a piece of ex vivo liver sample, and return plate electrode was positioned at the bottom of the liver. Two home made notch filters connected by a shielded cable and tuned to 63.5 MHz were inserted between the generator (Radionics cooled tip RF system) and the needle and return electrode. T° mapping was performed with similar protocol for 50W RF energy deposition (without electrode cooling) and 80W (with water cooling using standard Radionics pump). RF power was applied until tissue impedance, continuously controlled by the generator, increased to high values (> 300 Ohms) due to tissue desiccation close to electrode tip. Temperature and necrosis maps were calculated and displayed in real-time on a separate console with Thermoguide software (IGT SA, Pessac, France) during MR acquisition. Estimation of necrosis dimensions was calculated offline with the same software.

Results

Figure 1 displays typical temperature (A) color map and necrosis estimate (B) superimposed to anatomical image (grey levels) of the central slice obtained during RF ablation at 80W with electrode cooling (see Figure legend for colors code label). Images were of sufficient quality to exploit phase maps for quantitative temperature calculation (apart from susceptibility artifact due to the needle material), and no artifacts due to electrode cooling could be observed. Figure 2 presents time evolution of the temperature in a single pixel located 10 mm lateral to the needle. A continuous increase of T° can be observed during RF power deposition (between marked positions 1 and 2) together with a slow decrease after RF power was switched off (3), due to heat diffusion. An abrupt T° drop is observed between positions 2 and 3, corresponding to rapid tissue impedance increase due to desiccation at electrode tip. Corresponding images depicted large artifacts and could not be exploited for T° calculation. Except for that short period, temperature uncertainty remained in the range of 1°C during the complete experiment. An elliptic shape for necrosis was systematically found (n=6), with small and large axis in the range of 45mm x 60mm for 80W (electrode cooling) and 30mm x 40mm for 50W (without electrode cooling).

Discussion

This study shows that quantitative T° mapping with excellent precision is feasible during RF ablation on ex vivo liver with the use of a cooled monopolar electrode and appropriate filters and cables. In addition, this feasibility study demonstrates that temperature imaging could help in the optimisation of ablation procedures, varying RF output power and/or electrode cooling, to achieve the largest lesion size in the minimum experimental time. Combination of such apparatus with MRI sequences adapted to *in vivo* liver T° imaging [4] could make real-time quantitative temperature monitoring possible, especially to study influence of big vessel flow on local temperature distribution and resulting necrosis.

References

[1] Lepetit-coiffé M. et al, ESMRMB 2002 proceedings, 251. [2] Vigen K.et al, ISMRM 2003 proceedings, 685. [3] Ishihara Y et al, Proceedings of the 11th Annual Meeting of SMRM, Berlin, 1992. p 4803. [4] Weidensteiner C et al, Magn Reson Med 2003, 50(2):322-30.

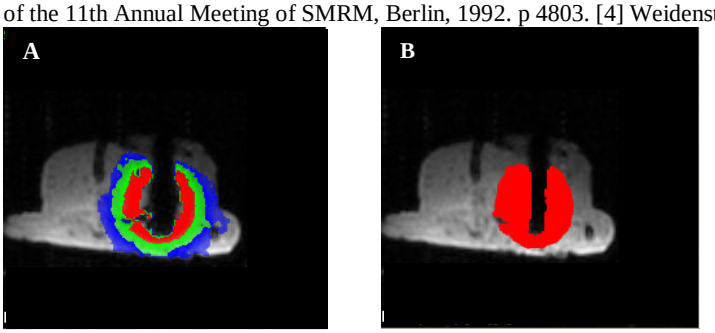

Figure 1: Temperature (A) and necrosis (B) maps obtained during RF ablation.
A : Blue, Green and Red colors correspond to T° increase of +10°C, +20°C and +30°C respectively.
B: pixels in which thermal dose has reached lethal threshold are colored in Red

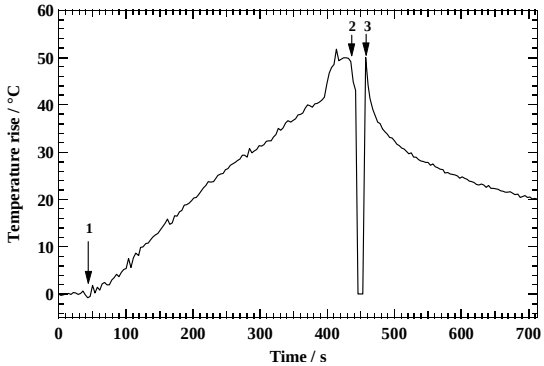

Figure 2: Temperature evolution in a single pixel located 10 mm lateral to the needle position
1: heating start, 2 : tissue impedance increase and
3: output power reset to zero