Fast Mapping of RF-Induced Heating along Conductive Wires by MRI Thermometry

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Introduction: Conductive implants are in most cases a strict contraindication for MRI examinations. Applied RF pulse power during the MRI measurement can lead to severe heating of the surrounding tissue. An understanding and mapping of these heating effects is therefore crucial to determine under which circumstances patient examinations are safe. The use of fiberoptic probes is the standard procedure for monitoring these heating effects. For *in vivo* applications thermocouple wires are mainly used. However, the observed temperature increase is highly dependent on the positioning of such a probe as it can only determine the temperature locally. Temperature mapping with MRI after RF heating can be used, but cooling effects during imaging lead to significant underestimation of the heating effect. In this work we monitored the temperature with a MRI temperature mapping technique during high-power RF heating, induced by the imaging sequence itself. The results were compared with the readings from a fiberoptic probe.

Methods: All experiments were performed on a Siemens Vision 1.5 T imaging system. An insulated conductive wire with a length of 20 cm was placed on the left side of a 20 l gel phantom (conductivity 0.47 S/m, T1 relaxation time 650 ms). Temperature mapping was performed using a modified PRF (proton resonance frequency) method [1] containing a high power RF pulse as shown in figure 1. The additional RF pulse was slice selective with the slice positioned outside the chosen FoV and therefore not influencing temperature mapping. Averaged RF power of the sequence was set to 10 W/kg bodyweight by adjusting the additional RF pulse. A series of 100 phase images was recorded consecutively with the modified sequence. Temperature maps were calculated by substracting each phase image from a reference image and utilising the near-linear temperature-dependency of the resonance frequency for water protons.

Results: The last image from the series of 100 temperature maps is shown in figure 2. The heating effect of the wire can be clearly seen by the heat spreading in the surrounding gel at both wire ends. Significant heating in other regions can not be observed. Figure 3 shows the chronological sequence of the wire tip's temperature measured by the fiberoptic probe and the MRI measured temperature of the surrounding gel averaged over the region indicated in figure 2. The two measurements show excellent agreement.

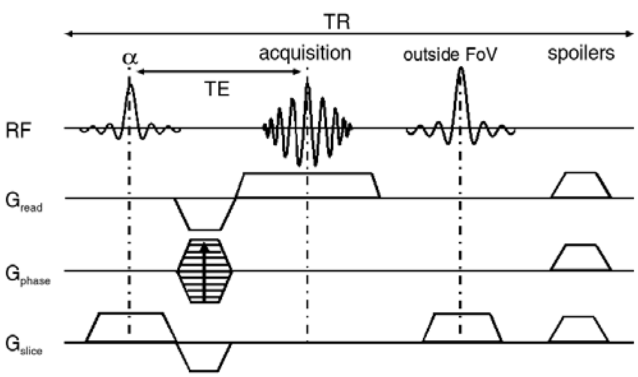

Fig. 1: GRE sequence plus an "off-resonant" heating pulse

Conclusion: It could clearly be shown that both MRI heating and MRI temperature mapping can be combined to form a powerful tool that overcomes the disadvantage of a single point temperature measurement by a fiberoptic probe. The accuracy achieved in this study was sufficient and comparable results to the fiberoptic probe were obtained. This method can be used in safety testing environments for the non-invasive monitoring of the heating of implants during MRI examinations.

Acknowledgement: This work was supported by the Bayerische Forschungsstiftung (Bavarian Research Foundation).

References: [1] Y Ishihara et al.: "A precise and fast temperature mapping method using water proton chemical shift", MRM **34**:814-823, 1995

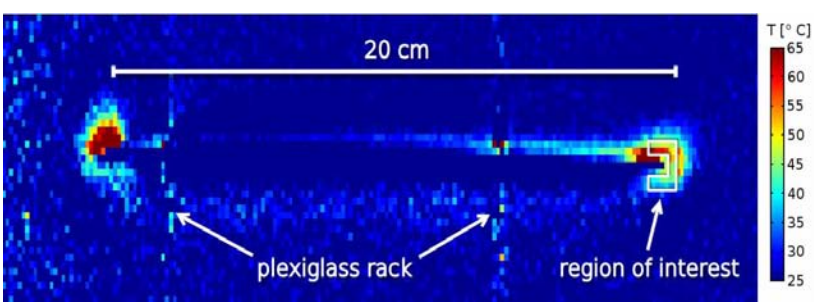

Fig. 2: MRI temperature map of the wire after 6 min of MRI heating (sagittal plane). It is clearly visible that the heating mainly takes place the wire ends. The plexiglass rack, which was used to fixate the wire, is visible by the two line artifacts. The temperature values from the marked region were used to obtain an averaged temperature which was compared to the temperature readings of the fiberoptic probe (figure 3).

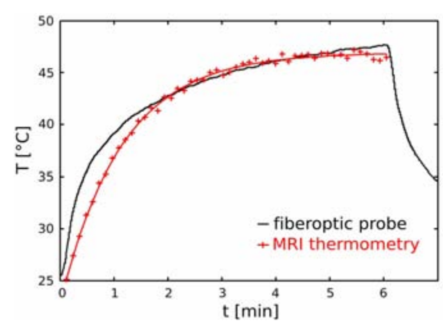

Fig. 3: Temperature from the transversal MRI temperature maps averaged over region of interest (red) in comparison to the readings from the fiberoptic probe (black).