A combined approach to assessing safety of depth electrodes and microwires at 3 Tesla

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The Food and Drug Administration recently expressed concern regarding the variability of implant heating experiments [1]. Electrically conductive implants can inadvertently act as antennae during magnetic resonance imaging (MRI) and couple radio frequency (RF) energy into the body [2]. The underlying cause of MR-related heating can be investigated directly by measuring the antenna behavior of an implant, avoiding the simplifications associated with computer models or computations. The purpose of this study was to investigate MR-related heating at 3-Tesla/128 MHz associated with a depth electrode and microwire array commonly used for diagnosis and treatment planning in Temporal Lobe Epilepsy (TLE). The aims were to determine the location of the dominant source of heating, the feasibility of safe use, and if possible to modify the design to allow for safe use. An additional aim was to identify the heating affect of changing the resistive load on the implant.

Heating Experiments: A head/torso gelled-saline filled phantom was used with flouroptic probes to measure the MR-related heating (ASTM F2182-02a). Three depth electrodes with microwire arrays, described previously [3], were bundled around the flouroptic probes (Model 3100 Fluoroptic Thermometry System, Luxtron, Santa Clara, CA, USA) (Fig. 1). The tips of the flouroptic probes and deployed along the lengths of the electrodes to determine whether the electrodes, microwires, or transcranial screws caused the majority of the heating. The bundle configuration was chosen to minimize the contact of flouroptic probes with circulating fluids, and to exceed the clustering of electrodes used clinically. The bundle was centered on the side of the head and positioned orthogonally to the magnet bore as though implanted in the patient temporal lobe. The entire transcranial screws were immersed in the saline with the aim of maximizing heating. A 3-Tesla/128-MHz MR system (Excite, Software G3.0-052B, General Electric Healthcare, Milwaukee, WI) was used with the transmit body RF coil and a reported 3.0 W/Kg specific absorption rate. Heating below 1ºC was observed on the left side. The loading condition of the microwire array was switched from an open-circuit to a closed-circuit configuration by plugging the clinically used 10-pin connector with an improvised metallic structure; MR-related heating revealed an additional increase in temperature of 2ºC. Unsafe heating in excess of 6ºC above baseline was observed on the right side for the open circuit configuration. In all experiments the flouroptic probe at the microwire tips indicated the greatest temperature changes, suggesting a possible resonance condition. To remove the suspected resonance condition without repositioning the electrode bundle, non-magnetic scissors were used to clip the excess microwire leads, resulting in a 75% reduction in MR-related heating (Fig. 2).

Antenna Characterization: The antenna behavior of implants was investigated with a network analyzer (HP 3495A, Agilent Technologies, Inc., Palo Alto, CA, USA) to characterize the resonant frequency profile. The electrodes where immersed in physiological saline. Adjacent intact microwire leads were probed through the clinically used connector. Adjacent pairs of clipped leads were soldered directly to a small coaxial connector. The resonant frequencies of the intact electrodes were found to be 129 $\pm$ 6 MHz in saline (n=6), corresponding to the operating frequency for MRI of protons at 3 Tesla, 128 MHz. Complex impedance measurements did not indicate a resonant condition for the clipped electrodes within 15 MHz of the operating frequency while the electrode and microwire leads lay flat (n=4).

Conclusions: The findings indicated that unsafe heating conditions were correlated to the presence of electrode self-resonance near the MR frequency. These preliminary data suggest that characterization of the resonance frequency can contribute to a better understanding of the safety profile for a given electrode to ensure safe MRI of patients with implants.

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[3] I Fried *et al*., J Neurosurg. (91):697–705, 1999

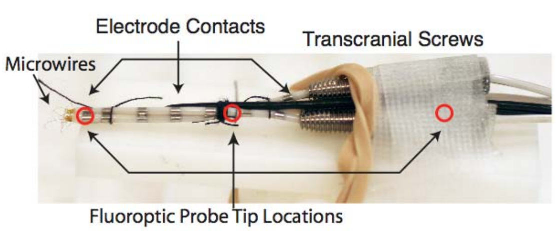

Figure 1 Electrode and microwire arrays with temperature probes. Circles indicate location of temperature measurements.

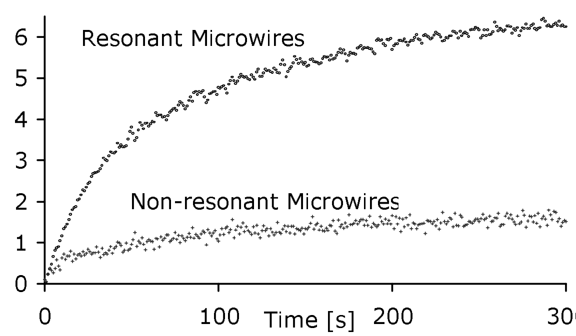

Figure 2 MR-related heating of resonant and non-resonant microwires. Resonant frequency determined with network analyzer. Clinically used microwires were found to resonate near the operating frequency of 3-Tesla proton MRI.