Reducing and Monitoring Resonant Heating in MR Guidewires

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Introduction In this work, we study the feasibility of lossy capacitive top-loading for reduction of MR guidewire heating. Previous work reports temperature rises within phantoms due to coupling of RF energy to a conductive catheter guidewire under MRI [1,2,3]. We propose to significantly reduce the resonant heating at the distal tip (within the patient) by coupling a lossy dielectric at the proximal end of the wire. We monitored interactions with temperature sensors and with optically-coupled MR-compatible RF current transducers.

Methods We performed experiments in a GE Signa 1.5 T scanner and in a custom-built shielded 8-rung RF birdcage coil with 1.5 m length and 60 cm diameter (Boston Scientific). As a guidewire, we placed a 24 AWG bare wire axially at a 20-25 cm radius (Figure 1). We used a Luxtron m3300 Biomedical Lab Kit fluoroptic temperature measurement system. To measure temperature rises, we secured the fiberoptic temperature sensor within 1mm from the tip of the wire and placed both of these into a catheter Y-adapter to create a constrained heating area with access to a small saline bath (Figure 1, inset).

To demonstrate Q-spoiling and top-loading of our wire antenna we applied sufficient RF power in each setup to produce heating in a non-resonant length (160cm). We fixed the wire within the bore, and then introduced a saline-filled bottle until the wire was a distance (*d*) within the bottle. In the birdcage, we measured the temperature rise after 30 seconds (from a baseline of 21.5 ºC) for insertion distances from 0-11 cm for each of four saline concentrations (distilled water, 30mM, 60mM, and 1M NaCl solutions). We also monitored induced RF currents for each load condition, at reduced RF power levels, with an optically-coupled current transducer (Figure 2). In the 1.5 T scanner, we measured the peak temperature rise from 5 seconds of a minimum-TE high flip-angle SSFP sequence.

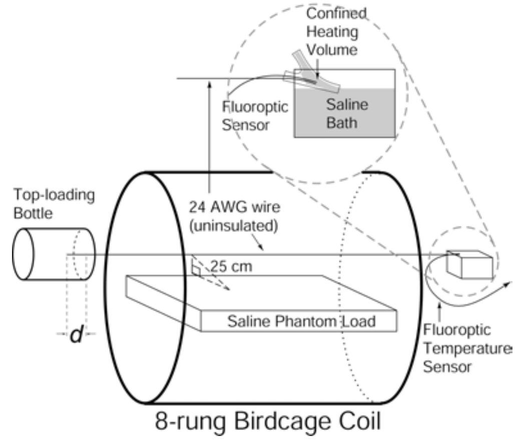

Figure 1: Temperature measurement setup.

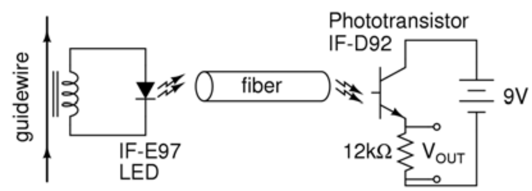

Figure 2: Optically-coupled RF current transducer. 11-turn, air-core, 1.5 cm toroidal inductor couples current from guidewire. DC output voltage is proportional to rectified RF current.

Results Figure 3 displays the 30-second temperature rise in the wire for each dielectric loading condition in the birdcage coil, and Fig. 4 contains similar curves for the 1.5 T scanner experiments. In both cases, the 160 cm wire is shorter than a half-wavelength for resonance in air without top-loading, but the higher dielectric of the distilled water creates a clear resonance condition when wire insertion is 5 cm. For higher-loss dielectrics, we measure diminishing resonance effects—similar to Q-spoiling in other contexts—that eventually reduce measured heating to the baseline for a 1M NaCl solution. RF current transducers showed commensurate reduction in induced currents with loading.

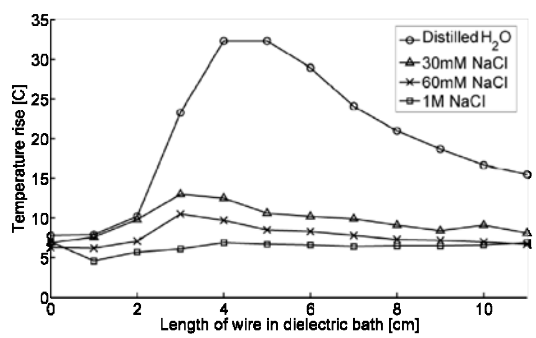

Figure 3: Birdcage heating. As lossy dielectric loading increases, heating at distal end decreases.

Discussion and Conclusion Our prior work indicates that the use of surface coil/array excitation can reduce guidewire coupling [4]. The results of this study suggest that lossy dielectric loading proximally can also reduce resonant heating distally in a guidewire under MRI. In effect, we can reduce the resonant Q of the guidewire in a controlled manner. In future it may be possible to combine antenna top-loading and current-monitoring techniques to detect and prevent unsafe RF interactions.

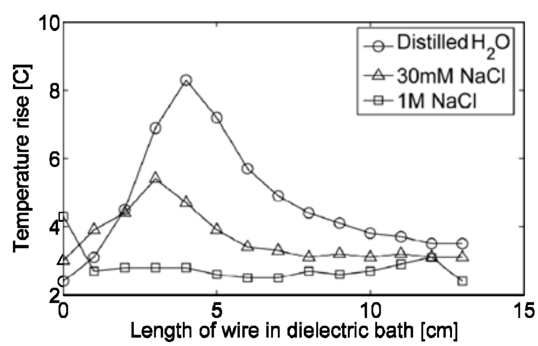

Figure 4: 1.5 T heating. Proximal loading lowers distal heating.

References

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