An Evaluation of the Potential Extent of Catheter Heating During MR Imaging

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Introduction

There is substantial interest in MR guidance of some endovascular procedures due to the ability of MR to provide soft tissue contrast and functional information. This has led to the development of numerous "XMR" suites that readily provide access to both x-ray and MR imaging modalities. A major concern with the use of MR imaging during endovascular procedures has been the potential safety risks associated with catheters and guidewires. These devices contain long metallic components that provide the mechanical properties necessary for remote steering. These long metallic structures may be ferrous or non-ferrous, and tend to contain an uninterrupted length of conductor. Ferrous catheters are easily screened with deflection tests; however, the long conductive structures associated with a catheter braid or guidewire have the potential to interact with the RF energy emitted by the scanner, producing focal temperature elevations near the device. There exists precedent, however, for MR imaging in patients with implants that contain long conductive structures such as deep brain stimulators and even cardiac pacemakers. Additional precautions are recommended for these patients, including more stringent specific absorption rate (SAR) limits and close patient monitoring.

The purpose of this study was to establish the extent to which catheter heating occurs under and assortment of geometric conditions and SAR exposure levels. The goal was to identify conditions under which MR imaging may be performed in patients undergoing a neurological endovascular procedure with a non-ferrous, but braided, catheter in place.

Methods

Experiments were performed on two 1.5T MR systems (Siemens Avanto, Philips Achieva) with a phantom conforming to ASTM test method F2182-02. Non-ferrous 0.035" guidewires and 5F braided catheters were embedded in a polyacrilamide gel (0.35% NaCl, 6.5% acrylamide, 0.3% bisacrylamide, 0.05% TEMED, and 0.08% ammonium persulfate in distilled water) in geometries typical of a patient undergoing neuro-endovascular therapy via femoral access and more extreme lateral offsets. Fiber-optic temperature sensors (FOT Lab Kit, Luxtron Corp) that were capable of 1 Hz sampling where placed at several points along the endovascular devices and in the homogeneous background gel. Temperature rise was monitored during turbo spin echo acquisitions with SAR values ranging from 0.1–4.0 W/Kg. All acquisitions were 2 minutes long and temperature rise over this period and the initial rate of temperature rise (fit to the first 30s of imaging) were quantified. In order to explore different device lengths, experiments were performed with the head portion of the phantom gelled and the body portion aqueous (0.35% NaCl in distilled water). Temperature sensors were all placed in the head portion of the phantom for these studies and the length of endovascular device submerged in the aqueous body section was incrementally shorted. Sensitivity to position along the z-axis of the scanner was investigated by prescribing offsets to the landmark position (initially set at mid-point of the head).

Results

The rate of temperature rise in the background during 4W/kg scanning was found to be 0.04±0.02 (Philips) and 0.05±0.03 (Siemens) ^{0}C/min. Immersed length tuning was initially performed on both MR systems with endovascular devices highly offset towards the sides of the phantom. Length tuning produced comparable results, with the Philips system demonstrating maximal guidewire heating at an immersed length of 78 cm (Figure 1) while the peak occurred at 73 cm on Siemens. The maximal rate of heating was 2.0 (Philips) and 2.7 (Siemens) ^{0}C/min for guidewires and 1.1 (Philips) and 1.6 (Siemens) ^{0}C/min for catheters. Peak catheter heating occurred at immersed lengths of 78 cm (Philips) and 88cm (Siemens). Catheters that were oriented with anatomically realistic offsets produced heating levels at ~40-50% of those demonstrated with highly offset devices. Heating scaled linearly with SAR exposure level and became indecipherable from background heating below 0.2 W/kg. Heating over the last 20 cm of the devices varied substantially and peak heating was demonstrated at the conductor tip and 10-12 cm proximal to the tip. Heating was maximized when the devices distal tip extended slightly beyond isocenter. Catheters in anatomically realistic geometries produced a worst case focal rate of temperature increase of approximately 15x's higher than background.

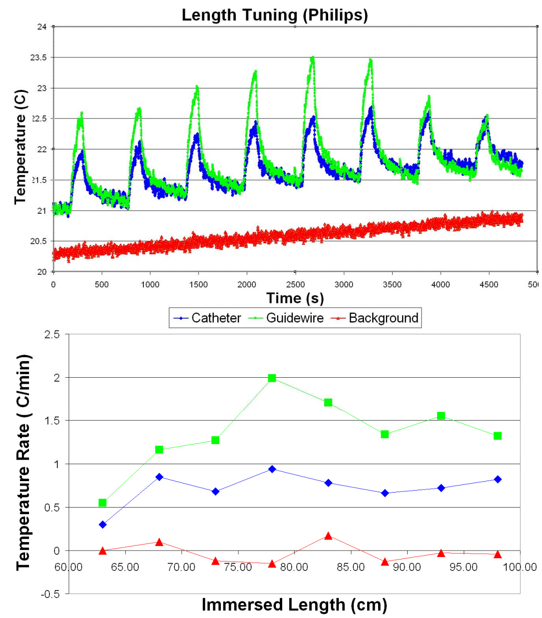

Figure 1: Temperature rise adjacent to a catheter and guidewire is shown as a function of immersed device length. Both devices were maximally offset in the phantom and exposed to 4 W/kg scans. The top panel shows the temperature response to a series of 2-minute long scans with 8 minute cool down periods. Immersed length of the devices was sequentially shortened by 5 cm and the initial rate of temperature rise is shown as a function of immersed length (bottom).

Conclusions

Endovascular devices can locally enhance RF deposition and produce focal hot-spots adjacent to the device. Factors that can affect the magnitude of focal heating include the position and orientation of the device within the magnet bore, internalized length of device, position along the device and strength of incident RF energy. The actual temperature rise demonstrated in these studies was modest, but well above the temperature response of the background gel. Guidewires consistently showed greater heating than braided catheters and reduced SAR acquisitions effectively limited focal temperature rises. A combination of SAR limits (<0.2 W/kg) and imaging duty cycle restrictions appear to be sufficient to permit MR imaging in catheterized patients without concern for thermal injury.