Vascular Flow Effects on RF Heating of Passive Implants: The use of a Flow Modified ASTM F2182 Phantom in a Siemens Tim Trio 3T Scanner

Alan Leewood, PhD[1], David Gross, BS[1], Jeff Crompton, PhD[2], Sergei Yushanov, PhD[2], Orlando P. Simonetti, PhD[3], and Yu Ding, PhD[3]
[1]*MED Institute, Inc., West Lafayette, IN, United States,* [2]*AltaSim Technologies, LLC, Columbus, OH, United States,* [3]*The Ohio State University, Columbus, OH, United States*

Introduction

MR safety of electrically conductive passive implants is directly related to heating of the tissue in close proximity to the device when subjected to RF powered E-fields. Cell death has been found to be a complex function of time and temperature. Current MR safety methodology relies primarily on experimental methods (ASTM F2182), that use a gel phantom which by its high viscosity negates convective heat transfer often providing overly conservative temperature results. When utilized *in vivo,* many passive devices (e.g., stents) located in the vasculature experience cooling due to blood flowing past the device. This study experimentally investigates the effect of flow on the temperature rise of an implanted device when exposed to RF energy of a typical MR scan. Multiphysics simulations are presented, which demonstrate excellent correlation with the flow experiments. The use of simulation technology will extend MR safety evaluation of devices beyond the limitations of the current test method by representing more physiologically relevant conditions which result in more accurate temperature predictions.

Methods

An ASTM F2182 gel phantom was modified to include an 8mm diameter ***flow*** channel through the phantom. A peristaltic pump circulated water through the phantom flow channel including a 10cm long, thin walled titanium cylinder (representing a simplified passive implant) placed in the phantom at a position that maximized local heating. Two test configurations were evaluated in a Siemens Tim Trio 3T MR Scanner powered for 15 minutes: A 10cm long, thin walled tube immersed in a standard ASTM F2182 gel phantom (considered the *no flow* condition) and the same titanium tube with water circulating through the modified flow phantom at a flow rate of 2 L/min. The same 15 minute pulse sequence (TR = 271ms, flip angle =180°) operating at a system-reported whole-body SAR of 4W/kg was run on the two phantom setups; once with the standard phantom (*no flow*) and once with the phantom containing the modified flow channels. Transient temperatures were measured at the ends of the tube with standard Fluoroptic® temperature probes. Multiphysics FEA software was used to perform a fully coupled analysis (i.e., electromagnetics, fluid dynamics and heat transfer) to predict the resulting temperature rise.

Results

The 10cm long, titanium thin walled tube (ID=8mm) was tested in accordance with ASTM F2182 (i.e., *no flow*) in a 3T Scanner operating at a whole-body SAR of 4W/kg, produced a 20 °C temperature rise at the ends of the cylinder on conclusion of a 15 minute scan. The measured temperature rise at the ends of the cylinder when water was flowing through the tube was found to be 10 °C. Simulations using Multiphysics modeling showed visually ***strong*** correlation with both of the experimental conditions.

Discussion

As expected, vascular flow provided significant cooling to the thin walled tube with a 50% reduction in peak temperature at the end of the 15 minute scan. These results suggest that the current RF heating test method, ASTM F2182, is too conservative for many vascular implants as it is likely to predict temperatures higher than physically realized *in vivo*. Ultimately, this raises the issue that clinically indicated MRI scans may be inappropriately withheld from patients with implanted devices because RF heating concerns were based on overly conservative test methods. Future work will replace the thin walled tube with a cannula cut stent and the flow media with a more blood-like, non-Newtonian fluid.

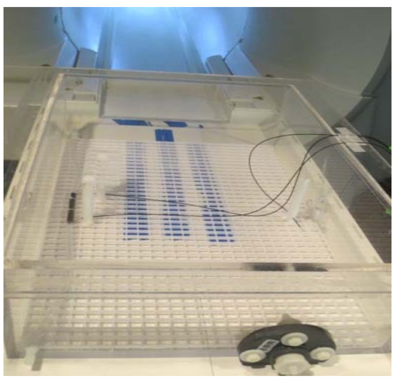
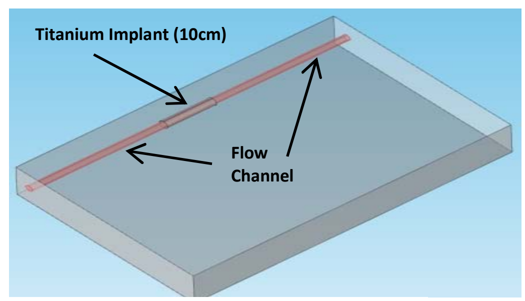


Figure 1: Photo of the modified ASTM F2182 *flow* phantom on the patient table of a Siemens Tim Trio 3T MR Scanner. The silicone flow tubes, 10cm long thin wall titanium tube and Fluoroptic® temperature probes are visible inside the phantom.

Figure 2: CAD Multiphysics schematic of the ASTM F2182 gel phantom with a 10mm OD flow channel passing through the phantom end-to-end and a 10cm long titanium thin wall tube situated at the isocenter of the phantom-scanner bore.



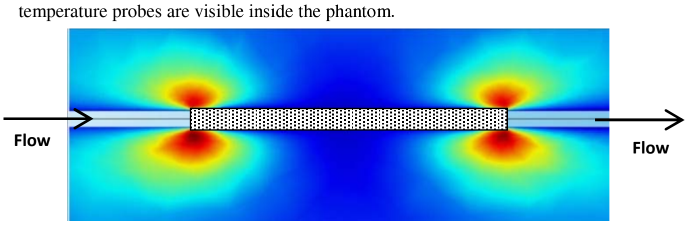


Figure 3: Temperature contour from the Multiphysics simulation showing the flow channel passing through the thin wall tube. While the peak temperature is still at the ends of the tube, the maximum temperature is reduced by 50% (see Figure 4) due to the flow (2 L/min).

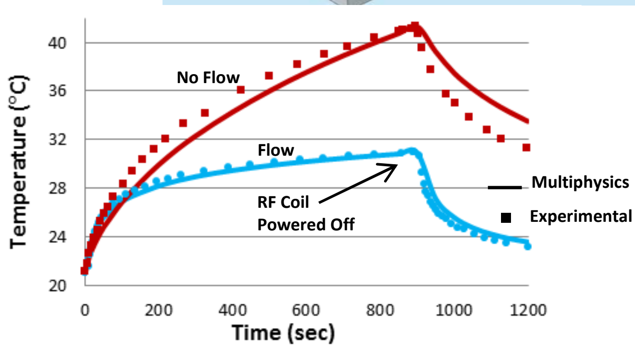


Figure 4: Temperature history as measured (and simulated) at the ends of the 10cm titanium tube over a 20 minute period (RF Coil powered for 15 minutes) for two cases: the base case which is the standard ASTM F2182 phantom [no flow channels] and the second the modified phantom with flow channels passing through the thin walled tube at a flow rate of 2 L/min.