FDTD Simulations of Implantable Devices at 3 and 7 Tesla

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Introduction

Proliferation of high and ultra high field scanners at a staggering rate will inevitably be ensued with the daunting question of implantable devices compatibility and safety (1-3). This fact compounded by the technical difficulty of the experimental assessment of implantable devices compatibility gives credence to computational techniques (4) for such task. As the finite difference time domain (FDTD) method has been a widely used technique for characterization of RF heating, it is an excellent candidate to render an accurate estimate for heating of implantable devices in MRI. In this work, we present results of computational simulations for calculating specific absorption rate (SAR) associated with typical brain aneurysm clips at 3T and 7T. These calculations indicate a considerable difference in heating pattern in the near vicinity of these devices at high fields. In addition, the results also demonstrate the capabilities of electromagnetic simulation (FDTD) in assessment of implanted medical devices in high field MRI scanners to ensure that it doesn't exceed established SAR levels for exposure to electromagnetic energy.

Methods

FDTD method was utilized to model the aneurism clip as shown in Figure 1. The clip was inserted in the brain inside a transverse electromagnetic coil tuned to 3T as well as 7T. Several SAR studies were performed to assess the effects of field strength, polarization, placement, and accuracy in the modeling.

Results:

Study 1: Fig. 2 demonstrates that the presence of the aneurism clips increases the local SAR within close proximity to these clips. This increase however was lower than the peak SAR (measured elsewhere in the head) at 3T but was the highest at 7T.

Study 2: Fig. 3 demonstrates that the placement of the aneurism clips significantly affects the local SARs due to the polarization of fields produced by the coil. This is clearly apparent from the 3T results where the transverse placement produces the least SAR as the transverse electric field in the middle axial plane of the coil is minimal. The 7T results however illustrate otherwise, clearly demonstrating the non-uniformity of the electric field associated with 300 MHz operation which in turns affects the interactions with the aneurism clips.

Study 3: Fig. 4 demonstrates that accurate modeling in the FDTD technique may affect the calculated results. As such, non-conventional techniques such as non-uniform meshing, conformal modeling (shown in the work), subgridding maybe needed to accurately assess the SARs associated with implanted devices.

Discussion:

Considering that an accurate assessment of RF heating requires proper electromagnetic characterization of tissue and its physical properties combined with its spatial representation, the FDTD's method is naturally suited for these studies. Given the unfeasibility of in-vivo assessment of SAR in human and animal subjects with such accuracy, our computational tool showed a valuable ability to model the tissue structure at a high resolution to meet the necessary accuracy that could play a vital role in allaying the legitimate safety concerns of implantable devices for applications at low and high field scanners.

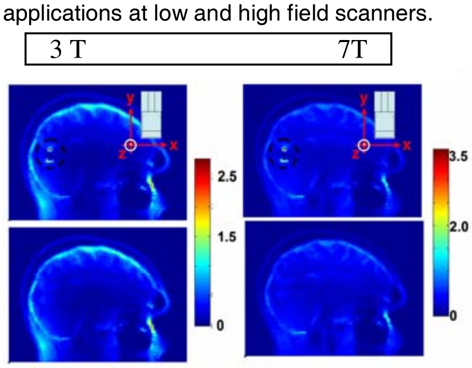

Fig. 2: Presence of Aneurism Clip Study. SAR (Watts/Kg) before (bottom) and after (top) placement of the aneurism clip at 3T and 7T.

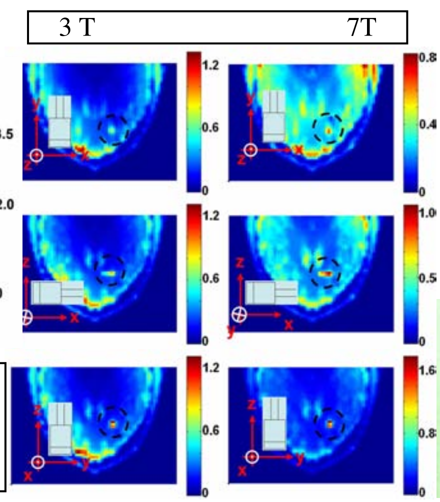

Fig. 3: Polarization Study. SAR (Watts/Kg) due to the placement of the aneurism clip in different orientations at 3T and 7T.

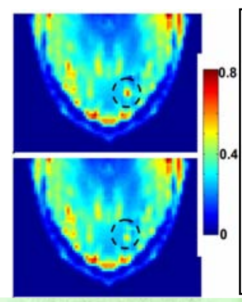

Fig. 4: FDTD Accuracy Study. SAR (Watts/Kg) at 7T due to modeling the aneurism clip in a stair-stepped manner (top) & to a slanted modification in the FDTD cell (bottom).

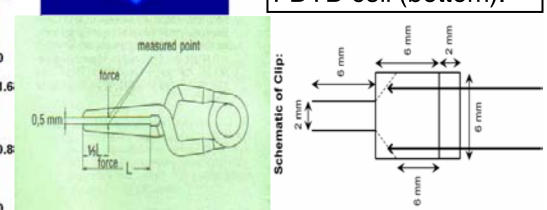

Fig. 1: Schematic of the aneurism clip and its FDTD grid including the use of modified slanted cells to account for the clip curvature.

References:

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