SAR and temperature rise within tissues near a medical implant

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Introduction

With the increased usage of pacemakers and other medical implants, there is a growing interest in determining the safety of patients with these devices during magnetic resonance imaging (MRI) procedure. The mechanism for potential adverse events is likely to involve the metallic leads and electrodes heating of these devices, resulting in injury to surrounding tissues. In this abstract, numerical modeling work are employed to calculate electromagnetic energy deposition and thermal heating in tissues near metallic implants when patients are undergoing an MRI procedure.

Methods

Simulation Method: The XFDTD software package was used to calculate the specific absorption rate (SAR) distribution due to radio frequency (RF) electromagnetic radiation from a MRI birdcage coil. The obtained SAR information was provided to a thermal modeling tool to obtain temperature distributions and resultant temperature rises surrounding the metallic implants. The temperature increase due to the induced SAR was determined by subtracting the calculated "basal" temperature profile, where there was no input SAR, from the temperature profile when the SAR was present. Simulation Setup The implanted device model, shown in Figure 1, composed of a metallic box, an electrode and lead wires. The metallic box was modeled as a cylinder with a radius of 2 cm and a height of 1 cm; the electrode was a cubic with an edge length equal to 0.5 cm. This specific implant model was incorporated inside the male body with the box close to the lung tissue and the electrode lead inserted into heart region. The metallic material for the whole implant model was modeled as Titanium alloy. The birdcage coil used here was constructed with 16 equally spaced rungs of a length of 70 cm. These rungs were terminated in two circular coils with diameters of 70 cm. This coil was tuned to work at MRI resonance frequencies. The male model with or without the implant model was then placed in supine position with the back of the model around 24 cm away from the inner edge of the coil and the navel almost at the center of the coil, as shown in Figure 1. The resultant models were discretized in XFDTD software with cubical finite-difference mesh cells of length 5.0 mm.

Results

Simulations are carried out for both 1.5T and 3.0 MRI systems. The resultant SAR values for the 1.5T and 3T systems were normalized to 2W/kg whole body SAR value, which is the IEC recommended safety limit for normal mode MRI operation. Figure 2 illustrates the normalized un-averaged SAR values and temperature rises (ΔTs) along a mid-frontal plane inside the human body (with and without the implanted device) exposed to the 1.5T and 3T MRI systems. It is found that the SAR and ΔT in the region close to the implanted device are much higher than those of non-implant exposure. The maximum 10-gram averaged SAR values were also calculated for both cases. As expected, the heart tissue with the metallic implant has considerable larger maximum 10-g averaged SAR values and temperature rises than those without the implant. Although the maximum 10-gram averaged SAR values for the heart tissue are still under the IEC limit of 10W/g, the maximum temperature rise inside the heart tissue is 1.0 ^{o}C, which is well above the 0.05 ^{o}C of the situation without the implant. Also indicated in the figure, SAR and temperature rise pattern can be significantly different, which is caused by the different thermal conductivities of different tissues.

Conclusions

Electromagnetic and thermal modelings were performed to evaluate the SAR and temperature distribution around a metallic implanted device inside a male body. Significant variations of SAR level and temperature increase occurred around the region when an implant was present. It was found that depending on different systems, the maximum temperature rises may reside in different tissues. For the particular medical implant studied here, maximum 10-gram averaged SAR and temperature rises are within the safety limits. However, more comprehensive modeling/experiment work shall be carried out to truly understand the safety issues related to various medical implantable devices under exposure to MRI scans.

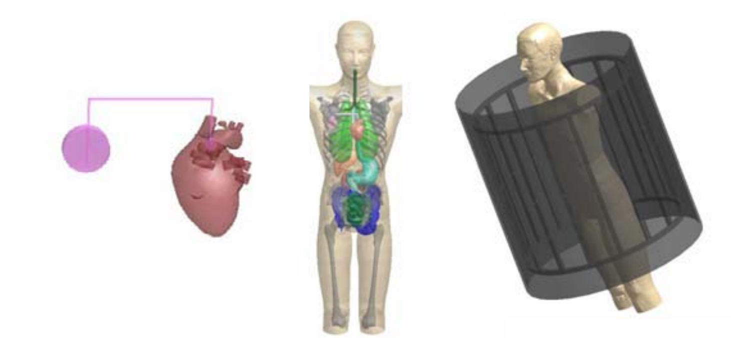

Figure 1 Simulation setup 1) implantable device model, 2) implantable device and body model, and 3) body model within MRI RF coil

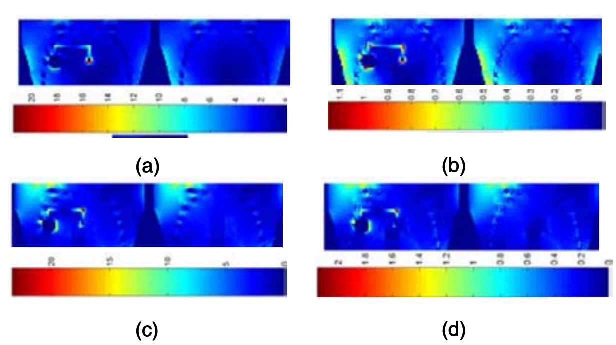

Figure 2. SAR and temperature rise with/without medical implants. a) 1.5T SAR w/wo implants. b). 1.5 T temperature rise w/wo implants. c) 3T SAR w/wo implants. d). 3T temperature rise w/wo implants.