RF-Induced Electromagnetic Fields and Implant Heating in MRI

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Introduction

Magnetic resonance imaging (MRI) is still contraindicated for routine examinations of patients with implanted electronic devices such as pacemakers, implantable cardioverter defibrillators or deep brain stimulators. This is because the electromagnetic fields inherent to the MRI methodology tend to interact with these devices, potentially causing dangerous side effects [1]. One major concern is the capability of elongated conductive implants, e.g. pacemaker leads, to pick up and concentrate radiofrequency (RF) energy in an MRI environment, eventually causing high temperature rises in the vicinity of the implant. It is still not fully understood under which circumstances this harmful effect takes place [2]. In the present study, our goal was to systematically investigate the distribution of RF-induced E-fields inside a human body-like phantom and put the results in perspective with regard to RF-induced implant heating depending on implant position in the phantom filling medium.

Methods

Two techniques were used to assess RF interactions inside a head/torso phantom (89x42cm) filled with 45kg of a saline gel with a conductivity of 4.7mS/cm: (1) voltage measurements and (2) temperature measurements. (1) Voltage measurements were performed with a custom-made measurement system allowing for determination of local E-field components in terms of voltage gradients inside the saline during MRI. The sensor of the measurement system, a 5cm dipole, was systematically positioned in three orthogonal orientations (X, Y, Z) at 432 measurement points distributed over three layers inside the phantom filling to assess the spatial distribution of RF-induced E-fields in the saline. (2) Measurements of RF-related implant heating in relation to the implant's position within the gel were performed with a fiber optic temperature measurement system. The temperature rise at the bare tips of an insulated steel rod of 20cm length in the phantom filling was measured during MRI at 180 geometric positions of the implant sample. All measurements were performed at 1.5T on a Siemens Avanto as well as a Siemens Vision MRI system, using standardized sequences.

Results

A total of 1296 readings with the voltage measurement system and 180 temperature measurements were performed on each scanner. The basic E-field distribution in the Avanto and Vision scanners showed no major differences. A tilted left-right asymmetry of the E-field was observed in both scanners. The largest voltage gradients were found close to and oriented parallel to the phantom walls. Figure 1 shows the distribution of the RF-related E-field inside the phantom gel in the Avanto scanner. Implant heating (ΔT) in the Avanto scanner dependent on the implant position in the gel is shown in Figure 2. Highest implant heating was found when the implant was placed in positions corresponding to locations with highest relative E-field strength.

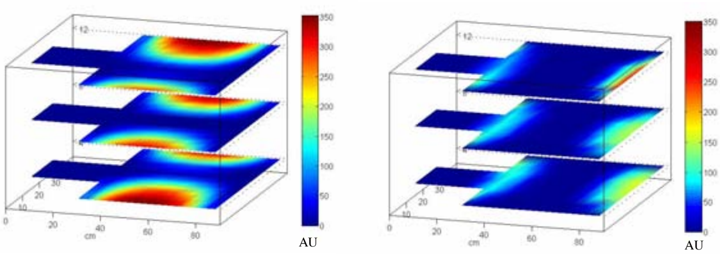

Fig. 1: Distribution of local RF-induced E-fields in the Avanto parallel (left) and perpendicular (right) to the scanner bore. Arbitrary units (AU) represent measured sensor output.

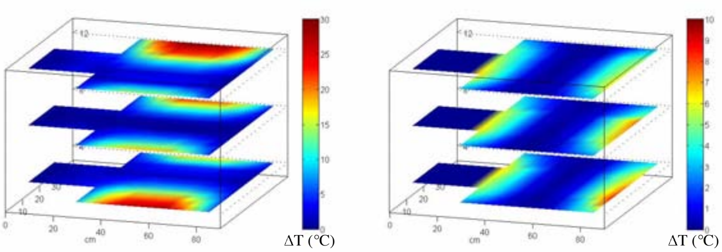

Fig. 2: RF-induced implant heating in the Avanto dependent on implant position, oriented parallel (left) and perpendicular (right) to scanner bore. Note different scaling of the images.

Conclusion

Distribution and relative strength of the E-fields induced inside a human body-like phantom during MRI at 1.5T was assessed for two MR systems. The RF-induced heating at an implant sample showed strong sensitivity to implant positioning in very close correlation to relative local E-field strength. A specific hazard for RF-related tissue heating in MRI arises if elongated conductive implants follow the course of the induced E-fields in the body.

References

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