A Comparison of RF-Induced Heating for a Range of Titanium Rods at 1.5T and 3T

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Synopsis

RF induced heating is a principal concern for patients with active implantable medical devices (AIMDs). MRI exams at >1.5T are often avoided, largely because the SAR increases with the square of field strength, thus RF-induced heating is expected to increase. RF induced heating, however, also arises because of the antennae-like characteristics of the AIMD. Our objective was to compare RF-induced heating in rods with different lengths at 1.5T and 3T when the same B1+RMS was applied. Results suggest that for a specific device length, RF-induced heating is not always higher for increasing field strength.

Introduction

RF induced heating is a principal concern for patients with active implantable medical devices (AIMDs). MRI exams at >1.5T are often avoided, largely because the SAR increases with the square of field strength, thus RF-induced heating is expected to increase. RF induced heating, however, also arises because of the antennae-like characteristics of the AIMD. Thus, devices with a length that matches the scanner's RF half wavelength are expected to heat the most. Limited work has been done to characterize the behavior of devices of various lengths exposed to different field strengths while same RF power is applied. Therefore, the purpose of this work was to analyze the relationship between field strength and device length when the same B1+RMS was applied. To do so, a measurement of temperature increase (ΔT) at the end of the titanium rods of different lengths placed at a range of locations in the ASTM phantom was performed at 1.5T and 3T.

Methods

Experiments were performed within the ASTM torso phantom filled with a saline gel (e=80,s=0.47S/m)[1]. A comparison of RF induced device heating with respect to the device length and placement within the phantom was performed at 1.5T (Siemens, Avanto Fit) and 3T (Siemens, Prisma). Four 1/8-inch diameter titanium rods with lengths matching the RF (in conductive media) wavelength, half-wavelength, and a quarter-wavelength (52cm, 26cm, 13cm, 6.5cm), were placed in nine different positions within the ASTM phantom. These nine positions corresponded to all combinations of anterior-mid-posterior and right-center-left positions (Fig. 1-A). To ensure that the same RF energy was applied throughout the experiments, a Turbo Spin Echo sequence (TSE) with constant B1+RMS (2.5μT at 1.5T and 3T) was used for 5 minutes at first level mode (~4W/kg) (Fig. 1-B). The background temperature was subtracted to obtain ΔT data at the end of each rod using fluoroptic temperature probes (Lumasense).

Results

A map of highest heating (ΔT_{max}) for the nine locations and four different rod lengths is shown in Fig. 2. To correlate ΔT with the E-field distribution obtained from electromagnetic (EM) simulations in the ASTM phantom (Fig. 3-A). The maps were normalized with respect of ΔT_{max} observed for each experiment (Fig. 3-B, C). For the four rods, ΔT_{max} was observed in highest E-field regions (anterior-left and posterior-right) at both 1.5T and 3T. Rod length had a direct effect on the observed magnitude of ΔT (Fig. 4). It was observed that for rods with length matching the scanners resonant half-wavelength ΔT_{max} was the greatest. Thus, higher heating was observed for the 26cm rod (7.9C) at 1.5T and for the 13cm rod (15.3C) at 3T. Importantly, however, for a given device at a specific location, ΔT was sometimes higher at 1.5T than 3T (Fig. 2 and 4).

Discussion

In this work, a comparison of RF-induced heating for a range of device lengths was explored for different device positions within the scanner and different field strengths. Device heating was shown to be dependent on field strength, device position, and the characteristic length of the device. The results suggest that devices with lengths ~13cm exhibit greater ΔT at 3T, while devices with lengths ~26cm exhibit greater ΔT at 1.5T. These early results suggest that RF-induced heating will not necessarily be worse when increasing field strength for a given range of device lengths. Thus, the contraindication of MRI examinations for patients with AIMDs at field strengths >1.5T due to RF-induced heating should be carefully re-evaluated.

Acknowledgements

1. NIH/NHLBI R21 HL127433

2. CONACyT, Mexico

References

1. ASTM F2182-11a, Standard Test Method for Measurement of Radio Frequency Induced Heating On or Near Passive Implants During Magnetic Resonance Imaging, ASTM International, West Conshohocken

Figures

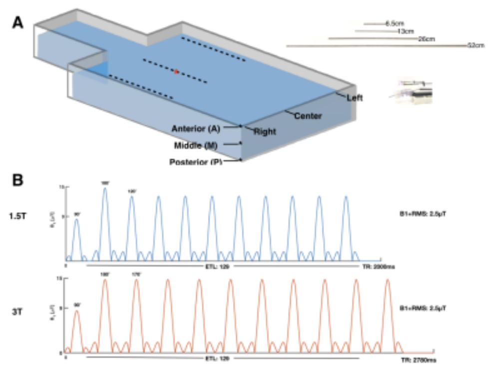

Fig. 1– (A) Positions for each rod within the ASTM phantom for RF-induced heating experiments. Thermal data was obtained for nine positions that resulted from the combination of anterior-middle-posterior and right-center-left placements. The center of the rod was placed at isocenter. The temperature probe was held in the same location relative to the rod tip throughout each experiment. **(B)** Turbo Spin Echo RF pulses with constant B1+RMS used at 1.5T and 3T.

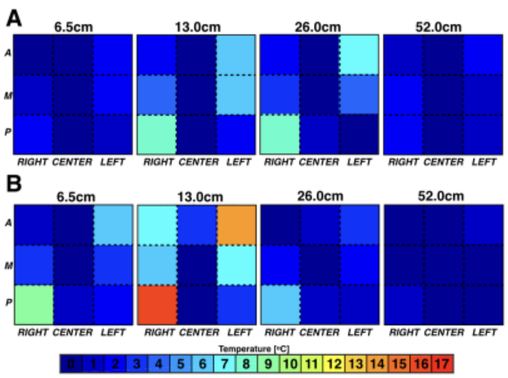

Fig. 2– ΔT_{max} for the four different length rods as a function of position within the scanner at 1.5T **(A)** and 3T **(B)**. Rod position, rod length, and field strength govern the observed ΔT_{max} values. Highest heating (ΔT_{max}) was observed in the areas of highest known E-field (posterior-right and anterior-left) and for the resonant half-wavelength (26cm for 1.5T and 13cm for 3T). Device heating was greater at 3T.

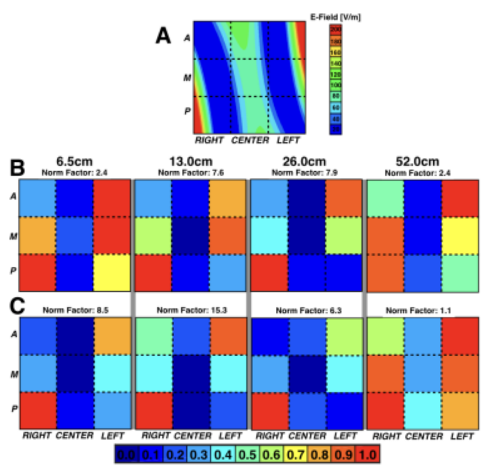

Fig. 3– (A) E-field distribution from EM simulations at 1.5T demonstrate the known asymmetry of the E-field. Normalized ΔT_{max} maps for each position in the phantom for the four rods at 1.5T **(B)** and 3T **(C)**. Each map was normalized by the maximum observed temperature for each device. Normalized ΔT_{max} was observed to be the greatest in regions where the RF induced E-field is known to be greatest.

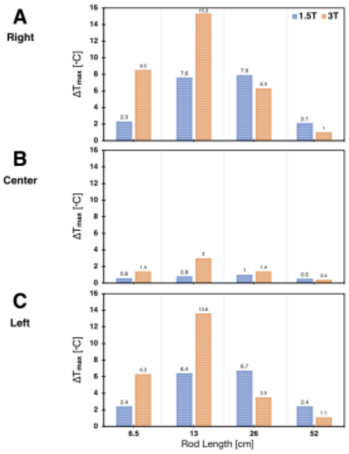

Fig. 4– Maximum ΔT_{max} observed for the right **(A)**, center **(B)** and left **(C)** placements of the rod for each rod length. Rods with length ≤13cm showed a greater ΔT_{max} at 3T than 1.5T. While rods with length ≥26cm showed a greater ΔT_{max} at 1.5T than 3T. For both field strengths, maximum ΔT_{max} was observed for rods with lengths that matched the scanners half-wavelength (13cm at 3T and 26cm at 1.5T).