RF heating along metallic catheters during a clinical MRI examination

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Synopsis

Heating of biological tissues along metallic wires placed in MRI scanner has become an important question with the development of interventional MRI. This paper presents results about temperature variation due to RF heating along a wire with two different lengths during a MRI examination. Measured values are compared with simulation results. Study shows that the temperature elevation may be important and does not appear only at wire tips.

Introduction

In the last few years the interest for using metallic guide wire or catheter for interventional MRI has considerably grown [1, 2]. The major issue is to insure patient safety against potential heating of tissues located in the metallic wire vicinity. The radiofrequency B_1 magnetic field is accompanied by an electric field E which induces currents (at the same frequency) in the metallic wire placed in the MR scanner. Thus, the metallic wire will concentrate the RF electric field and that may lead to an important temperature increase. The purpose of this study was to explore the temperature variation along metallic wires placed in the MRI tunnel during a routine clinical examination. Correlations between measured and calculated values of electric field are presented.

Methods

The temperature measurements along metallic guide have been made for two lengths of wire, λ and λ/4, where λ is the wavelength in air (4.7 m for ω = 63.7 MHz) of the RF B_1 field. Wires diameter was 0.14 mm. They were placed close to the wall tunnel (fig. 1) of a 1.5 T MR Symphony system (Siemens, Erlangen, Germany). To assess the local concentration of electric field E, the temperature variation in a small pieces of gel (0.9 % NaCl, σ = 1, ε_r = 81) placed around the wire was measured. The temperature variation was measured with an optical fiber temperature system (Luxtron model 3204, Luxtron Corporation, Northwestern Parkway, CA). The Luxtron temperature sensor was mounted adjacent to the wire with Teflon rubber. The tip of the sensor was outside of the Teflon rubber in order to measure the temperature increase of the adjacent gel. From measured temperature variations, the electric near field E is estimate with the formula: $E = (2\rho \cdot \Delta T \cdot c_s / \sigma \cdot t)^{1/2}$ (1) where ρ is the gel density, ΔT is the temperature variation, c_s is specific heat of the gel, σ is the electric conductivity of the gel and t is the scan duration. The sequence used was True-Fisp (TR/TE = 4.93/2.46 ms, α = 65°). The electromagnetic simulations of the experimental system were made assuming a plane wave excitation with FEKO (EM Software & Systems, Technopark, Stellenbosch, South Africa) using a P4 PC unit with 512 Mo RAM.

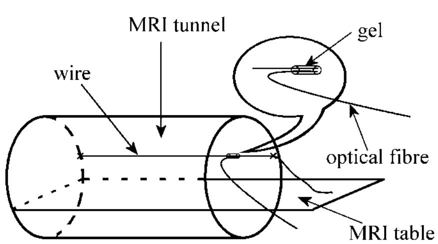

Fig. 1. Schematic experimental setup.

Results

The temperature measurements made along the wires for different distances starting from outside the MRI tunnel presents different shapes for the two wire lengths. Fig. 2a shows the temperature variation as a function of distance along the guide for a λ length of the wire and fig. 2b presents the simulated electric field (line) and the electric field estimated from temperature variation (black dots) normalized by its maximum value, and squared to be proportional with the temperature elevation according (1). The variation of temperature has two minimum for λ/4 and 3λ/4 and a maximum for λ/2. Fig. 3 presents the same variations for a λ/4 length wire. In this case a single minimum in the variation of temperature along the wire is obtain at λ/8.

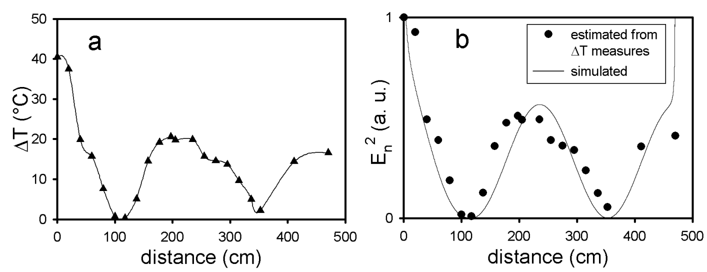

Fig. 2. Evaluation of (a) Temperature increase and (b) Normalized square electric field along a λ length wire.

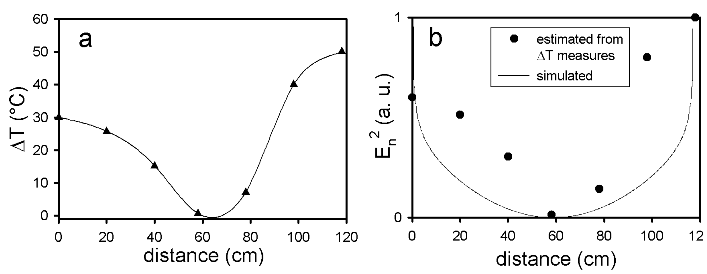

Fig. 3. Evaluation of (a) Temperature increase and (b) Normalized square electric field along a λ/4 length wire.

Discussions

We measured a very important heating (~ 40°C) of the gel in the vicinity of the wire. For λ length wire, temperature increase does not appear only at the tip of the wire proving that the heating effect is not only due to "tip effect". Calculated electric field and simulated electric field are in fairly good agreement. The fact that the excitation for the simulation is made with a plane wave and the electric field in the MRI is inhomogeneous could explain small local differences in fig. 2b and fig. 3b.

References

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