Influence from Static Magnetic Fields on Fiber-Optical Temperature Probes - Effects on Safety Measurements at 7T

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Introduction

Due to the increasing number of clinical studies in UHF-MRI at 7T the examination of patients with medical implants has become relevant. Implant specific test measurements should be conducted to calculate the specific absorption rate (SAR) in the surrounding of the implant either with direct E-field measurements [1] or with temperature measurements in phantom solution [2,3]. This study evaluates a commonly used non-magnetic fiber-optical temperature probe at different magnetic field strengths since field-dependent temperature offsets have been reported [4].

Materials and Methods

The fiber-optical temperature probes (FoTemp, OPTOcon GmbH, Dresden, Germany, Overall Accuracy:±1°C; Around the calibration point: ±0.1°C) were placed inside a water-filled silicon tube via peripheral venous catheters (Vasofix Braunüle Orange, B.Braun, Melsungen, Germany) in three different orientations respective to the magnetic field B_0 (black arrows in Fig.1). The silicon tube was connected to a temperature-controlled pump (F6/C25, Gbr. Haake GmbH, Karlsruhe, Germany) creating a closed flow circuit to keep a designated temperature constant during the whole experiment. For temperature calibration of the fiber probes a calibrated alcohol thermometer (temperature range: -10°C to +65°C) was included in circuit. A one-point calibration outside the magnet room was performed at 20°C. After calibration the setup shown in Fig. 1 was placed at at 12 positions in the UHF MR system (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) with field strengths between 2.0T and 7T. Two additional measurements with water at 60°C (second meas.: one-point calibration at 20°C; third meas.: one-point calibration at 60°C) were performed subsequently.

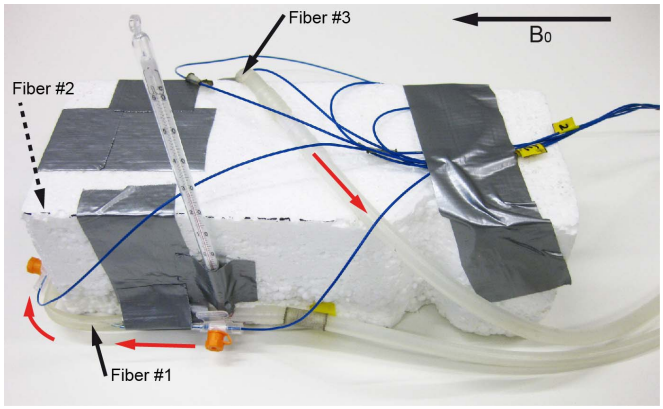

Fig.1: Holder for optical fibers and alcohol thermometer. Red arrows indicate water flow direction. The black arrows mark the positions of the fiber-optical probes.

Results

The results show a temperature drop of up to 2.6°C due to the magnetic field. Furthermore a varying ΔT at different temperatures up to 0.30°C between the first measurement (Fig.2: black line) and the second measurement (Fig.2: red line) could be seen, however, the accuracy of this measurement is lower (±1°C) due to the calibration to a significantly lower temperature. The third measurement (Fig.2: green line) with the 60°C calibration shows a difference in ΔT of 0.27°C. A temperature difference between the three orientations respective to B_0 was not observed.

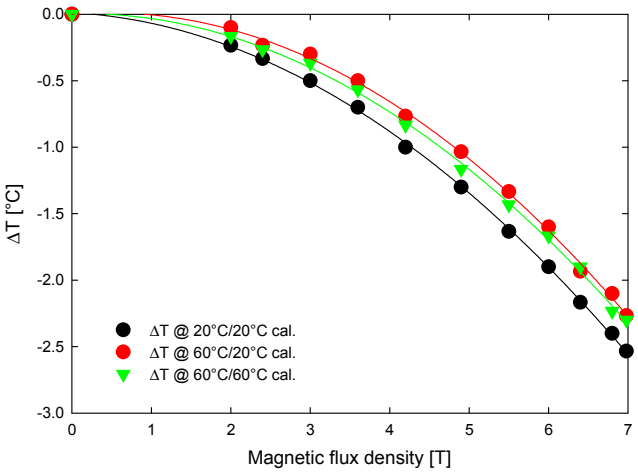

Fig.2: Temperature profile as a function of the magnetic flux density. The curves show the temperature changes in the three measurements (black: 20°C, calibrated on 20°C; red: 60°C, calibrated on 20°C; green: 60°C, calibrated on 60°C).

Discussion

It could be shown that temperature measurements with fiber-optical probes lead to errors in absolute temperature (B_0-dependent) and relative temperature changes (B_0-/temperature-dependent).
For MR safety measurements on implants the error can be neglected, if the fiber-optical thermometer is calibrated inside the magnet bore. For typical temperature risings inside the safety margin of the ASTM (ΔT < 1°C) [2] the relative temperature error would amount to 0.01°C, which is below the accuracy of ±0.1°C of the thermometer around its calibration point. Experiments with larger temperature changes (e.g. MR-thermometry) can only conducted, if both device-specific drifts are known and accounted for.

References

[1] Kraff, O et al.: # 3774, ISMRM 2011
[2] ASTM: F2182 - 09
[3] Rauschenberg, J et al.: #1580, ISMRM 2010
[4] Roland, U et al.: Sens Lett 2003; 1: 93-98