Individual prediction of a temperature rise of guidewires during MR-examinations using rf-field measurements: A comparison of 1.5 and 3 T

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Introduction: It is well known, that electroconductive material and the surrounding area can be heated by the rf-field of the scanner (1-3). In particular objects like guidewires, the length of which are nearby the half wavelength of rf-field, are problematic. The determining factor for the temperature rise (ΔT) is the electric component, the amplitude of which is not proportional to the magnetic induction and varies, depending on the construction of the transmitter coil. Thus the amount of ΔT depends on the position of the object inside the scanner bore. Especially during vascular interventions the geometric arrangement varies to a great extent. Therefore an individual estimation might be helpful. For this purpose, the aspect that a current flow through a wire could lead to an additive axially symmetric B_r-field, affecting the B_1-field, was utilised (4). This B_r causes a spatial change of the signal intensities close to the wire. The aim of this study was to prove, that changes of the field at different geometric arrangements and different frequencies of the transmitting coil reflects ΔT.

Methods: Copper wires and guidewires with different length were placed partly in a cylindric acrylic glass phantom (length 25 cm, Ø 15 cm) filled with copper sulfate solution. Transversal slices (thickness 5 mm) through the phantom at different geometric arrangements (Fig. 1a) were acquired by a 2D-gradientecho sequence (TR/TE 100/10 ms, FOV 230 mm, matrix 256x256) with exitation angles between 10° and 150°. In the preparation phase of every scan the receiver and transmitter gain were kept constant. The measurements were done on a 1.5 T (Philips, Intera 1.5) as well as on a 3 T scanner (Philips, Intera 3.0). For calculating the field changes the signal equation S (E1) was fitted to the measured data by optimising the scaling factor b of the flipangle α. Additional temperature measurements were done for comparison at each geometrical situation with a fiber optical sensor (Luxtron 3000) during a TSE-sequence with an SAR of 3.9 W/kg.

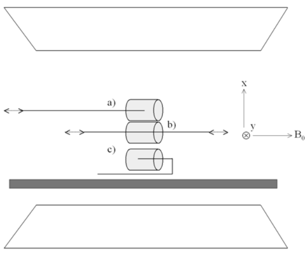
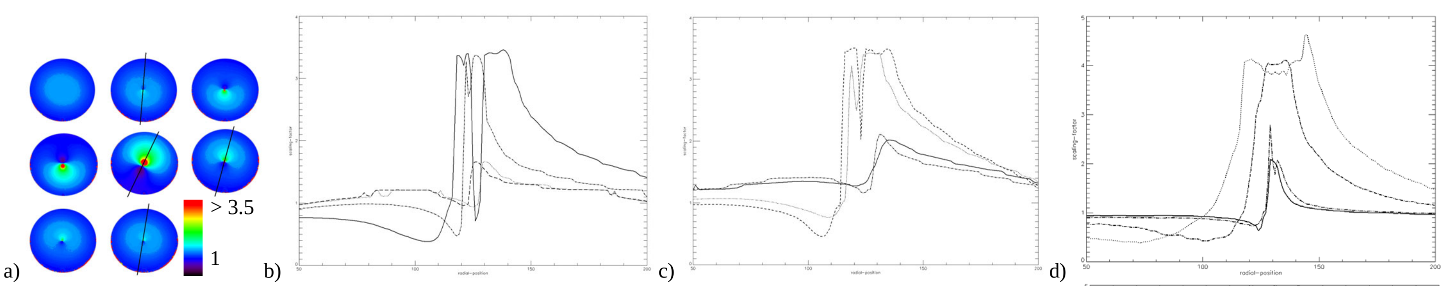


Fig. 1: Experimental setup: Positioning of the wire with different length with a) one end in the center of the bore, b) symmetric and c) U-shaped arrangement. The additional temperature measurements were done without the copper sulfate phantom, 10 sec after the start of the scan, at one end of the wire, immersed together with the sensor in a 3 ml 0.9 % NaCl solution..

$$S(X) \propto M_0 \frac{\sin(b\alpha)\cdot(1-e^{-TR/T1})e^{-TE/T2}}{1-e^{-TR/T1}\cdot\cos(b\alpha)} \qquad \text{E1}$$

$$F_t = F_1 + F_r = \begin{pmatrix} 0 \\ 1 \end{pmatrix} + \begin{pmatrix} -y/(x^2+y^2) \\ a\left(x/(x^2+y^2) \right) \end{pmatrix} \qquad \text{E2}$$

Results: During all measurements a correlation of the B1-field changes and ΔT was evident. Considering the calculated parameter maps (Fig. 2a), a rotation of the area with high values of the scaling factor against the length around the position of the wire arose. This applies to both, 1.5 T and 3 T. At a symmetric arrangement the amount of maximum ΔT was in the range of the half wavelength of the rf-field and shows a narrow maximum. The asymmetric situation (Fig. 1a) lead to an maximum ΔT at 1.5 m (1.5 T) and 0.8 m (3 T). However the maximum ΔT at 1.5 T was higher (48 °C) than the maximum ΔT at 3 T (11.5 °C). Figure 2b-d show the profiles through the cross section of the parameter maps with the direction of maximum changes. The widths of the curves always reflected ΔT. In the experimental setup with an U-shaped arrangement ΔT and the widths of the profiles increased when decreasing the distance between the distal wire end and the edge of the bore. When using non ferromagnetic diagnostic guidewires instead of copper wires, there were no significant differences with the exception of small (2 – 3 mm) susceptibility artefacts in the environment of the guidewire. By adding an axially symmetric F_r-field with a weighting factor to the homogeneous F_1-field (E2), the absolut values of the y-component of total field F_t reproduce the measured profiles (Fig. 2e). An increasing value of the factor a in E2 represents a rising induced current inside the wire.



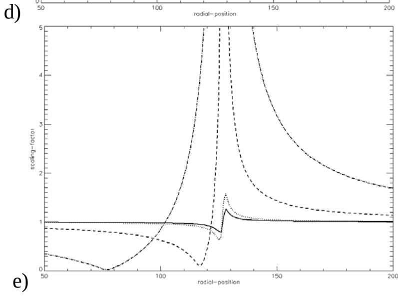


Fig. 2: a) Field changes at 3 T and an arrangement described in Figure 1a (from top left to down right: length 0, 0.26, 0.5 , 0.6, 0.7, 0.8, 0.9, 1 .0 m) and some corresponding profiles b) (length ···· 0.5, – 0.8, –·–0.9, --1 m). The lines in a) indicate the angulations of the chosen profiles. The wire was located in the center at position 128. c) Profiles at 3 T and symmetric case (length –0.26, ···1.4, --1.2, –·–2.0 m). d) Symmetric case at 1.5 T (length – 1.50, ···· 2.10, –·– 2.20, –··– 2.70 m). e) Absolute value of the y-component of F_t from equation E2 with different strength of the additional field (– small a, –·– high a).

Discussion: This study shows, that is possible to make an individual prognosis whether the geometrical situation fulfils the conditions for high temperature increases or not. For this prediction a sequence with a very low SAR could be used. The sequence used in the present study for measuring the rf-field showed no effect on the temperature. The changes of the rf-field correlates satisfactorily with the geometrical conditions for high temperature rises. The final amount of ΔT during the diagnostic imaging will be determined by the SAR. First investigations could demonstrate that this predictions are practicable as well in an inhomogeneous surrounding of a wire or implant.

1 A. Oppelt I. Delakis et al Proc. Intl. Soc. Magn. Reson. Med. 9 (2001) 2149
2 M.K. Konings C.J.G. Bakker Proc. Intl. Soc. Magn. Reson. Med. 7 (1999) 1004
3 F.G. Shellock, E. Kanal, MR Bioeffects, Raven Press (1994)
4 R. Girnus, V. Hesselmann et al Proc. Intl. Soc. Magn. Reson. Med. 11 (2003) 2448