Correlation of improved local SAR deposition with reduced shading close to hip implants

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Introduction:

MR imaging of patients with metal implants is challenging, both in terms of imaging artifacts and patient safety. Apart from susceptibility induced image distortions, also radiofrequency (RF) shading can be observed, in particular at higher field strength. Recent work[1,2] has shown that severe shading artifacts may occur near the femoral part of total hip arthroplasties (THA) and that this effect can be reduced by applying RF-transmit polarizations other than the common circularly polarized field. Since this approach comprises a reduction of induced electrical currents, a reduction of local SAR can be anticipated. In this work we present first numerical simulations to test this hypothesis.

Methods & Experiments:

Numerical simulations were performed with CST Studio Suite (CST AG, Darmstadt, Germany) to calculate the MR-effective amplitude $B_1$of the transmit field and the specific absorption rate (SAR) caused by the RF transmit field at 3T (123 MHz). In order to reflect the complex electronic structure of the human body, a voxel model of the human body (Hugo, integrated in CST) was placed inside the model of a birdcage coil. A titanium rod (length 0.2m) was located in the upper part of the right femoral bone. The excitation pulse was transmitted through the two feeding ports of the birdcage coil, separated by a geometric angular shift of 90°, generating a specified polarization by setting the ratio of amplitudes of the horizontal port over the vertical port R and a phase difference $\Delta\Phi$ for both ports. The distribution of local SAR for standard circular polarization (CP: $R = 1$, $\Delta\Phi = 90°$) was compared to an elliptical polarization (EP). The EP parameters were optimized to reduce the shading effects due to B_1 inhomogeneity. The axial cross section of the human body at the position of the titanium was approximated by a cylinder, and an analytical model[2] was used to determine the optimal polarization by minimizing the standard deviation of B_1 in a region of interest encircling the rod. The respective parameters for EP excitations were $R = 2$ and $\Delta\Phi = 102°$. The maps visualizing the local SAR deposition averaged over 10g were obtained for equal average B_1 in the central axial cross section of the implant.

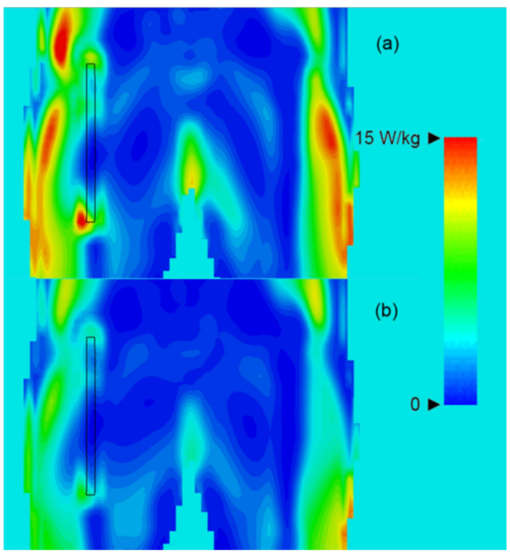

Fig. 2: Local SAR averaged over 10g in CP (a) and EP mode (b) in the same plane as in Figs. 1a,c. Hotspots at the end of the implant in CP mode is significantly reduced in EP mode

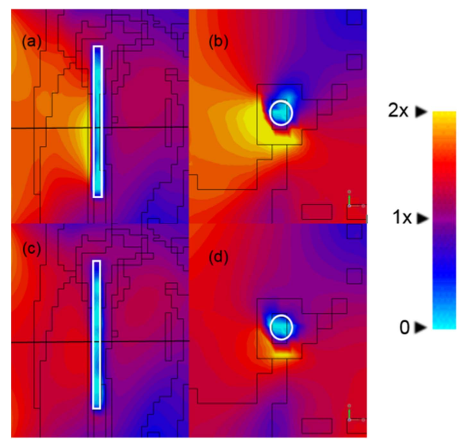

Fig. 1: B_1 maps near the implant (white outline) in CP (a, b) and EP (c, d). The coronal slice (a, c) is aligned with the center of the rod and the axial plane (b, d) is indicated by the black lines in the coronal images. Both pictures show the improvement of B_1 in EP.

Results:

Fig. 1 shows the simulated MR-effective amplitude B_1in proximity of the titanium. The right femoral bone is magnified in both coronal (a, c) and axial (b, d) orientation. While there is strong inhomogeneity in the vicinity of the cylinder in circular polarization (a, b), the elliptical polarization (c, d) shows significantly higher homogeneity in this region, indicating the improved image quality for EP compared to the standard CP. Fig. 2 shows the corresponding SAR maps, where local spots of high SAR are visible, especially near the bottom end of the metal rod in case of circular polarization (a). For the elliptical case, local SAR in this area is reduced by approximately a factor of two compared to the CP mode. It should be noted, that the whole body SAR (averaged) for both modes has approximately the same value (2W/kg).

Discussion & Conclusion:

B_1-shading can, especially at 3T, significantly obstruct image quality near femoral prosthesis, in particular for titanium hardware, where susceptibility artifacts are not dominant. Our current results suggest, that the use of polarized transmit fields can not only reduce B_1-shading artifacts, but may also decrease the local SAR in the vicinity of the implant. However, these results are limited due to the use of a simplified implant model (cylindrical rod). Further investigations are needed to explore various types of implants and also consider different body shapes.

References:

[1]Koch et al ISMRM 2010; p 3082, [2]Bachschmidt et al ISMRM 2014; p 1675