Reducing the peak SAR surrounding implanted lead tips in 3T MRI using a high-dielectric helmet former: a numerical feasibility study

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Audience: For those interested in novel ways to improve RF safety of implanted devices in MRI.

Introduction: The likelihood for a patient implanted with a pacemaker to require an MRI exam during their lives is as high as 75% [1]. There is significant concern about the strong deposition of RF energy, or SAR, around the lead tip of an implanted pacemaker during MRI[2]. Strategic arrangement of high permittivity materials has shown great promise for enhancing the strength of B1 field and reducing the SAR at high field MRI [3,4]. Here we use numerical methods to explore the possibility to reduce heating around the lead tip of a pacemaker with use of dielectric materials in a situation where a patient with an implanted pacemaker undergoes an MR scan of head and, as in most clinical MRI exams, a large birdcage coil is used in transmission and a local receive coil is used in reception.

Materials and Methods: A birdcage coil with 16 legs driven in a quadrature-type mode was used in the simulation at 3T. A 5mm-thick shell of high-dielectric materials in the shape of head coil former (3) was modeled about the head of an adult human body ("Duke,") as shown in Figure 1. The dielectric properties of the head coil former were manually optimized with respect to the homogeneity of the B_1 field in the brain and the peak SAR around the implanted lead tips.

Results: The presence of the high-dielectric head coil former enhances the B1+ field in the head relative to everywhere else, such that achieving a given B1+ field strength in the brain results in lower fields elsewhere when the high-dielectric former is present (Figure 2). Considering effects both on maximum 1g SAR near the lead tip divided by the square of mean B_1^+ field strength in the brain on the mid-axial plane and on field homogeneity, which is inversely related to the coefficient of variation of B_1^+ in the brain (Table 1), the optimal relative permittivity ϵ_r of the helmet former was found to be about 400. The transmit efficiency (average B_1^+ in brain divided by the square root of power dissipated in the entire body) was found to be 29% better with the helmet former present than without. The peak SAR around the lead tips normalized by the square of the magnitude of B_1^+ inside the head was found to be 42% lower with the helmet than without (Table 1, Figure 3).

Table 1. Results of B1 field of the transverse slice of head and SAR around the implanted lead tips

Relative permittivity of the head coil former	Peak SAR/$\lvert B_1^+\rvert^2$ W/(uT)^2	Coefficient of Variation of $\lvert B_1^+\rvert$
0	2.01e+9	0.146
300	1.46e+9	0.196
400	1.16e+9	0.196
500	0.958e+9	0.251
600	0.794e+9	0.259
700	0.663e+9	0.294

Discussion and Conclusion: The control of peak SAR around the implanted lead tips is an important issue in MRI. Here we show that the B1+ field can be enhanced in the head by adding a high-dielectric head coil former. Because of this it the power required to reach a desired B1+ field is much lower than when the former is not present. Both this and the re-distribution of field result in significant reduction of peak SAR.

References: [1]. Nazarian, et al., *Circ Arrhythm Electrophysiol*, 2013;6:419-428. [**2**]. Virtanen et al., Bioelectromag, 2006;27:431-439 **[3]**. Collins et al., ISMRM, 2013, p. 2797 [**4**]. Yang QX, et al. Magn Reson Med 2011; 65:358-362

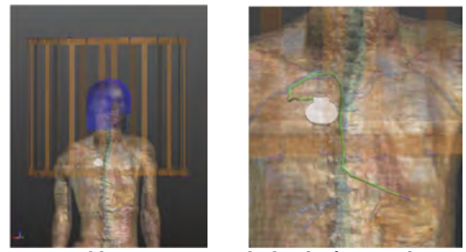

Fig.1 Problem geometry with detail of pacemaker on right. Numerical model of body birdcage coil (gold) loaded with human model "Duke" with high-dielectric head coil former (blue) and pacemaker (silver) with implanted lead (green), which is insulated everywhere but at the tip.

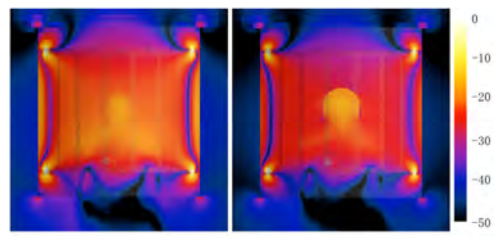

Fig.2 B_1 field distribution on the mid-coronal slice of head without (left) and with (right) the high-dielectric head coil former. Results are shown for the same average B1+ in brain with the log scale max being 10 times that average value.

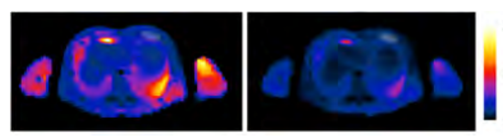

Fig. 3 Distribution of 1g SAR around the lead tips without the helmet former (left) and with the helmet former (right). Results are shown for the same average B1+ field strength in brain on the mid axial slice and shown as multiple of the maximum 1g SAR near the lead tip when the high-dielectric head coil former is present.