Use of resistances and resistive leads: implications on computed electric field and SAR values.

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INTRODUCTION. Previous studies [1] suggested an increase of Specific Absorption Rate (SAR) when using metallic Electroencephalography (EEG) electrodes and leads in MRI. We have studied leads with the same value of resistivity of commercially available carbon fibers, normally used for EEG and Electrocardiography (ECG) recording. A recent empirical study from Finland [2] reported a temperature increase of 12.3° C on a postmortem animal study at 3T with such carbon-fiber leads. The FDA databases [3] contain reports of accidents with Electrocardiography (ECG) electrodes even with newly (2001) designed fibers.

METHODS.

A High-Resolution head model (1x1x1mm^3) was used and eight tissues were segmented as described in [1]. All the simulations, based on the FDTD algorithm [4], were conducted at the frequency of 300 MHz, corresponding to a static MRI field of 7T. Two models were used for the electrode placement. The first model simulated one intracranial electrode with resistive lead (ρ=232Ω/m) and a birdcage RF coil [1]. A 8mm-diameter hole was made on the head model and the electrode was placed on the gray matter (Fig. 1, left, arrow). The lead was directed as shown in Figure 1.

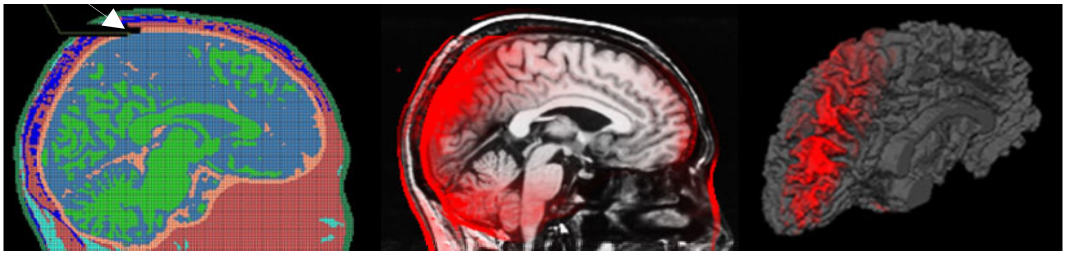

Fig. 1. *(Left). High-resolution head model with intracranial electrode and resistive lead. Eight tissues were segmented: bone and cartilage in pink; skin (dark green), CSF (light pink), white matter (green), gray matter (blue), fat (light blue), bone marrow (purple), and eyes (not visible). (Center) SAR distribution superimposed on the MRI images. (Right) SAR increases over the cortex shown in red. There was a two-fold increase of peak 1g-averaged SAR with respect to the no-electrode model.*

The second model (Fig. 2) considered a 31 electrode cap for EEG recording with surface RF coil [1] placed on the posterior part of the head. Three sub-cases were considered: 1) 31 electrodes connected to metallic leads with a 10KΩ resistance; 2) 31 electrodes connected to resistive leads (ρ=166Ω/m) with a 10KΩ resistance; 3) 31 electrodes directly connected to the resistive leads (ρ=166Ω/m).

RESULTS AND DISCUSSION.

In the first case studied, with intracranial electrode, there was a two-fold (x1.8) increase of peak 1g-averaged SAR with respect to the no-electrode model. Also, there was a two-fold (x1.7) increase for the SAR averaged over the gray matter, near the electrode.

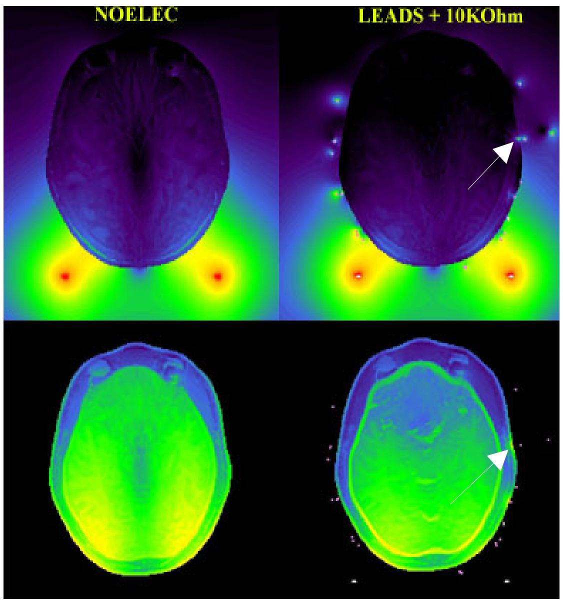

Fig. 2. *Electric Field (top) and SAR (bottom) for two cases (no-electrode and metallic leads plus 10KΩ resistance). The presence of the leads modifies the electric field, with related local increases of SAR (arrow)*

Figure 2 shows the electric field distribution without electrodes and with 31 electrodes/leads plus 10KΩ resistance. The metallic leads modified the distribution of the electric field, inducing increases of peak 1g-avg. SAR up to 15 times with respect to the no-electrode model (Table 1, 1st vs. 2nd column). Such increase depended on the type of leads and was higher with metallic leads and lower with resistive leads (Table 1, 2nd vs. 3rd column). The SAR increase was the same with or without a 10KΩ resistance between electrode and resistive lead (Table 1, 3rd vs. 4th column).

Table 1. Peak 1g-avg. SAR values (W/Kg) **with surface coil at 300 MHz -7T**

NO-ELEC	31 el. + metal. leads +10KΩ	31 el.+ res. leads +10KΩ	31 el. + res. leads
2.33	31.25	3.08	3.08

CONCLUSIONS.

The presence of leads modified the distribution of the electric field generated by the RF coil with increased values of peak 1g-averaged SAR. Such increase depended on the type of leads and was higher with metallic leads and lower with resistive leads. The SAR increase did not depend on the presence of a 10KΩ resistance between electrode and lead.

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