Quantitative Comparison of B_0 Field Distortion and Heating of EEG Electrodes at 4.0 T

T. K. Stevens[1,2], L. M. Klassen[1,2], S. M. Mirsattari[3], J. R. Ives[3], R. Bartha[2,4]

[1]Medical Biophysics, University of Western Ontario, London, Ontario, Canada, [2]Imaging Research Laboratories, Robarts Research Institute, London, Ontario, Canada, [3]Clinical Neurological Sciences, London Health Sciences Center, London, Ontario, Canada, [4]Diagnostic Radiology and Nuclear Medicine, University of Western Ontario, London, Ontario, Canada

Introduction

The possibility of surgical intervention for partial epilepsy patients is contingent on confident localization of the epileptogenic zones, predominantly by electroencephalography (EEG) and structural MRI. To avoid reductions in EEG monitoring time, scalp irritation/infection and increased demands on technical staff, it is desirable to have MR-compatible EEG electrodes and recording systems. Further need for this MR-compatible hardware comes from the research sector, in which simultaneous MR/EEG studies have shown great potential for investigating epileptic spike-correlated hemodynamics and metabolism. To evaluate MR-compatibility, the potential for the EEG hardware to degrade the quality of the MR signal must be considered, as well as the potential safety hazards associated with the interaction of this hardware and changing electromagnetic fields. *The purpose of this study was to quantitatively evaluate the B_0 field distortion and temperature increase of three types of EEG scalp electrodes during MR experiments at 4.0 T.* B_0 mapping was employed to quantify the field distortions, and thus the potential for signal dephasing due to the presence of the electrodes, and temperature change in the electrodes was monitored during the application of RF-intensive imaging and spectroscopy sequences.

Methods

Three types of EEG electrodes (*A*. hard brass with gold/nickel plating – conventional construction for clinical use, *B*. pure silver with gold plating – potentially MR-compatible construction[1], and *C*. silver/silver-chloride in a plastic mold – low quality construction for single-use) were sequentially positioned on a spherical saline phantom to maximize the magnetic flux due to RF pulses and tested for magnetic field distortions and temperature change. Imaging experiments were performed on a 4.0 T Varian $^{\text{UNITY}}$*INOVA* whole-body MR scanner equipped with Siemens Sonata gradients and a transmit/receive quadrature hybrid birdcage RF coil. Linear and $\mathbf{z}^2$ shims were used to optimize B_0 homogeneity over the volume of the phantom prior to the introduction of the electrodes. Frequency maps were acquired with a 3D multi-echo gradient echo (GE) sequence (*RASTAMAP*[2], 128 x 128 x 12 matrix size with 0.8 mm isotropic voxels, 32 averages, ~48 min duration) and anatomical images with the same orientation were acquired using an T_1-weighted 3D fast low-angle shot (FLASH) GE sequence. Field maps for each electrode were processed in MATLAB6 and were corrected for common reference distortions as well as temperature changes induced in the gradient coils and passive iron shims during the lengthy imaging experiments. Temperature monitoring of EEG electrodes was performed using a fibre-optic temperature probe (0.05°C resolution, 2 Hz refresh rate) connected to the surface of the electrodes. Following a 30-minute baseline reading, temperature measurements were taken during the application of several MR sequences (LASER spectroscopy[3], echo planar imaging (EPI), fast spin echo (FSE), T_1-weighted 3D FLASH GE), each separated by 8-minute baseline readings.

Results

The symmetric field distortion patterns (Fig. 1) observed for each electrode support the effectiveness of the applied field reference and temperature corrections. The frequency offset normal to the electrode surface was fit with a cubic decay (Fig. 2) to obtain coefficients representing the severity of field perturbation: 2.99e+5 Hz (electrode A), 5.87e+4 Hz (electrode B) and 3.05e+4 Hz (electrode C). No significant heat induction was observed during the application of any of the MR pulse sequences.

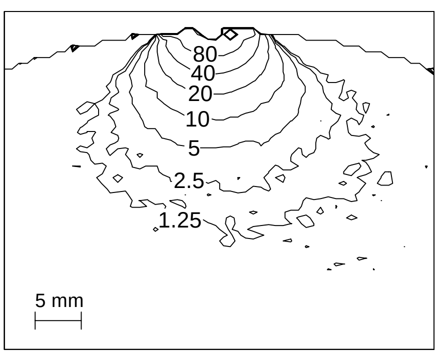
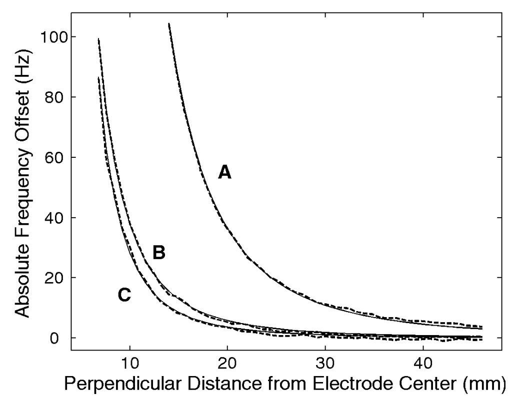


Fig. 1 (*left*). Absolute field distortion map (in Hz) of gold-plated pure silver EEG electrode at 4.0 T.

Fig. 2 (*right*). Comparison of spatially dependent field distortions generated by EEG electrodes: (A) gold/nickel-plated brass, (B) gold-plated pure silver, and (C) silver/silver-chloride. Solid lines represent experimental data and dashed lines represent fitted distortion decays.



Conclusions

The B_0 field distortions induced by the susceptibility of the EEG electrodes were directly mapped and the magnitudes of the induced frequency offsets were used to compare potential signal dephasing and loss during imaging/spectroscopy. As expected, the conventional *type A* electrode containing ferromagnetic nickel plating caused significantly greater field distortions than the *type B* and *C* electrodes, which were constructed of dielectric materials only. Although heat induction in EEG electrodes during the application of MR pulse sequences is a theoretical concern, particularly at high field strengths, no significant temperature changes were observed during these experiments at 4.0 T. This novel approach for *quantitative* analysis of MR-compatibility will be important for the evaluation of EEG scalp electrodes in future clinical and research studies.

References

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