Heating effects measured in EEG electrodes at 3T

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Introduction: The simultaneous acquisition of EEG and fMRI data provides a unique opportunity for investigating cerebral function at high spatial and temporal resolution, but simultaneous EEG-MRI raises several issues with regard to patient safety as the RF and gradient fields applied during MRI can induce currents that can lead to localised heating around the EEG electrodes. The RF fields are thought to represent the greatest risk in terms of induced currents and heating effects,[1] although previous studies have demonstrated that simultaneous EEG-fMRI data can be acquired safely at 1.5T under specific conditions.[2-4] However, to date only one study has experimentally investigated EEG electrode heating effects at field strengths of 3T or higher,[5] and while this study did not observe significant heating effects, it only considered a single electrode orientation. The purpose of this study was to investigate the temperature change induced in EEG electrodes placed in a variety of positions and orientations during MR imaging with several pulse sequences in routine use for both clinical and research MR imaging at 3T.

Methods: Testing was performed using a 3 Tesla GE TwinSpeed HD.x System (General Electric, Milwaukee, WI, USA) with a 19 channel MR compatible Ag/AgCl Quik-Cap EEG Cap. The EEG cap was fixed onto a uniform spherical test object and electrode Quik-Gel inserted to maintain good contact between the electrodes and the test object, mimicking the typical clinical setup (figure 1). Imaging was performed using an 8-channel receive-only head coil and a range of MRI sequences including gradient echo EPI, 3D fast IR-prepared spoiled gradient echo (SPGR), fast spin echo (FSE), DESPOT2 (based on steady state free precession (SSFP))[6], continuous arterial spin labelling (CASL), and quantitative magnetisation transfer (qMT). The temperature of the electrodes was monitored with a Luxtron fluoroptic thermometry system, and temperature measurements were acquired continuously at 0.5 second intervals during the scanning session. Each scan was followed by a rest period in order to allow the electrode temperatures to return to baseline. Two fluoroptic probes were used to record simultaneous temperature measurements from electrodes positioned at the right and left margins of the test object (oriented perpendicular to the right-left axis) during all MR sequences. Additional temperature measurements were acquired from electrodes positioned on the anterior, posterior, superior, and lateral oblique margins of the test object using two sequences with high reported SAR (CASL and SSFP).

Results: The maximum temperature rise (measured from the electrode positioned at the right-hand margin of the test object) exceeded 1º C for the CASL, SSFP, and qMT sequences; the maximum recorded temperature rise of 1.44 ºC was associated with the qMT sequence. The maximum temperature rise observed for all imaging sequences in this electrode is plotted against the reported SAR in figure 2. A strong correlation (R=0.95) is evident between the SAR and the recorded temperature rise. The maximum temperature rises observed for the CASL sequence for electrodes positioned at the right (R), left (L), anterior (A), posterior (P), and superior (S) margins of the test object are shown in figure 3. A large variation in recorded temperature change is seen across different electrode positions and orientations. The temperature recorded during the DESPOT2 (SSFP) sequence is shown in figure 4.

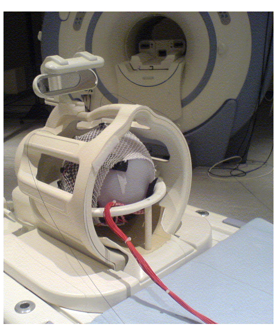

Figure 1

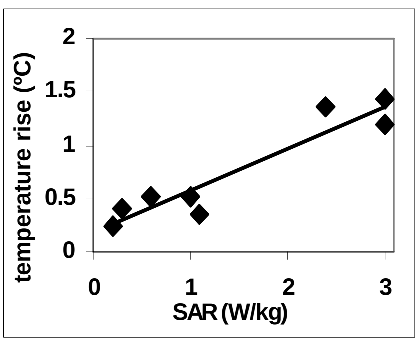

Figure 2

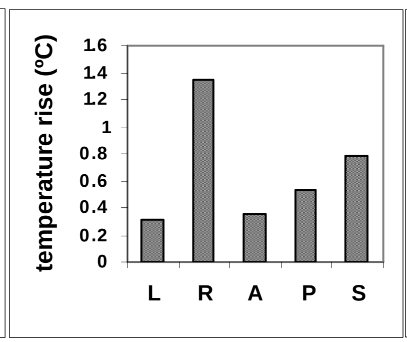

Figure 3

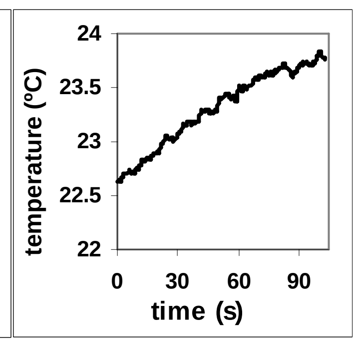

Figure 4

Discussion: This study observed small but measurable temperature increases in EEG electrodes during MR imaging with standard EPI, SPGR, and FSE sequences and significant temperature rises (>1º C) for sequences with reported SAR greater than 2 W/kg, (DESPOT2: 3 W/kg; CASL: 2.4 W/kg; qMT: 3W/kg). To our knowledge this is the first experimental demonstration of heating effects in EEG electrodes at 3T using MRI-compatible EEG electrodes and standard MRI pulse sequences. Although the temperature increases recorded in this study would be unlikely to cause tissue damage, the temporal profiles of the temperature measurements recorded during scanning indicate that temperature rises of greater than 2º C would be expected if high-SAR sequences were applied consecutively without allowing time for the electrodes to cool between scans. In addition, the large variation in the increase in temperature observed with varying electrode position and orientation indicates that experimental studies of electrode heating must consider all possible electrode configurations before a thorough assessment of the risks of heating effects can be performed.

References: [1] Lemieux et al. MRM 38:943-952 (1997). [2] Gotman et al. JMRI 23:906-920 (2006). [3] Lazeyras et al. JMRI. 13(6):943-8 (2001) [4] Mirsattari et al. Clin Neurophysiol. 115(9):2175-80 (2004). [5] Stevens et al. JMRI 25:872-877 (2007). [6] Deoni et al. MRM 53(1):237-41 (2005)