Radiofrequency-induced heating of intracranial stereo-EEG electrodes during MRI: a phantom study

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PURPOSE: Stereo-electroencephalography (SEEG) is a specific invasive EEG recording technique based on the use of depth intracranial EEG electrodes implanted to target deep or superficial cortical structures with the aim of precisely identifying focal epileptogenic networks in patients with drug-resistant epilepsy. Performing high-resolution MRI post implantation could significantly improve the accuracy of anatomical electrode localisation compared to CT fused to pre-implantation MRI[1]. Additionally, simultaneously acquired icEEG-fMRI could improve our understanding of the haemodynamic changes linked to epileptic activity[2,3]. There is however a risk of radiofrequency (RF) induced heating in the vicinity of intracranial electrodes[4], and the MRI safety of SEEG electrodes with skull-fixation titanium anchor bolts has not yet been explicitly addressed in the literature. Building on our previous experience of testing alternative intra-cranial EEG electrodes[5,6] we assessed temperature changes (ΔT) during MRI at the tip of SEEG electrodes (AdTech, Racine, USA) in a phantom considering different clinical scenarios.

METHODS: A torso phantom was filled with a gel of poly-acrylic acid partial sodium salt, as described in previous study[5]. Temperature recordings were made using a fibre optic temperature thermometer (Neoptix, Canada). Temperature probes were attached to the tips of 2 SEEG electrodes positioned either parallel or perpendicular to B_0. A third probe was positioned in the phantom away from electrodes and bolts and acted as a control reference. Measurements were performed at 1.5T (Avanto, Siemens, Erlangen, Germany) and 3T (Trio, Siemens, Erlangen, Germany) using a transmit-receive head coil, and a body transmit coil with a receive-only 12-channel head coil, during a 6 min Turbo Spin Echo sequence (scanner-estimated head SAR: 3 W/Kg, B1RMS 4.3μT). ΔT was calculated by subtraction of a baseline value (averaged temperature for 30s prior to MRI sequence) for each time-point during the scan. Additionally, to simulate simultaneous icEEG-fMRI conditions, the effect of connecting the electrodes to cable extensions and the EEG amplifier was investigated at 1.5T using the transmit-receive head coil during the above TSE sequence and a standard fMRI EPI acquisition.

RESULTS: Representative results are shown in figure 1: when scanning the electrode tails only, the maximum ΔT did not exceed 1°C in any of the measurements at 1.5T. However ΔT rose to +3.6°C at the tip of the electrode parallel to B_0 using the 3T body transmit coil. At 1.5T, connecting the unterminated cable extensions to the electrode tails produced a ΔT of 4.1°C at the tip of the electrode parallel to B_0; when the extensions were terminated by connection to the EEG amplifier, ΔT remained at 0.8°C for both electrodes. For the 1.5T scanner with head transmit-receive coil, the head SAR of a standard fMRI protocol was 0.1 W/kg and ΔT remained below our experimental thermometry precision (≤0.1 °C) in all measurements.

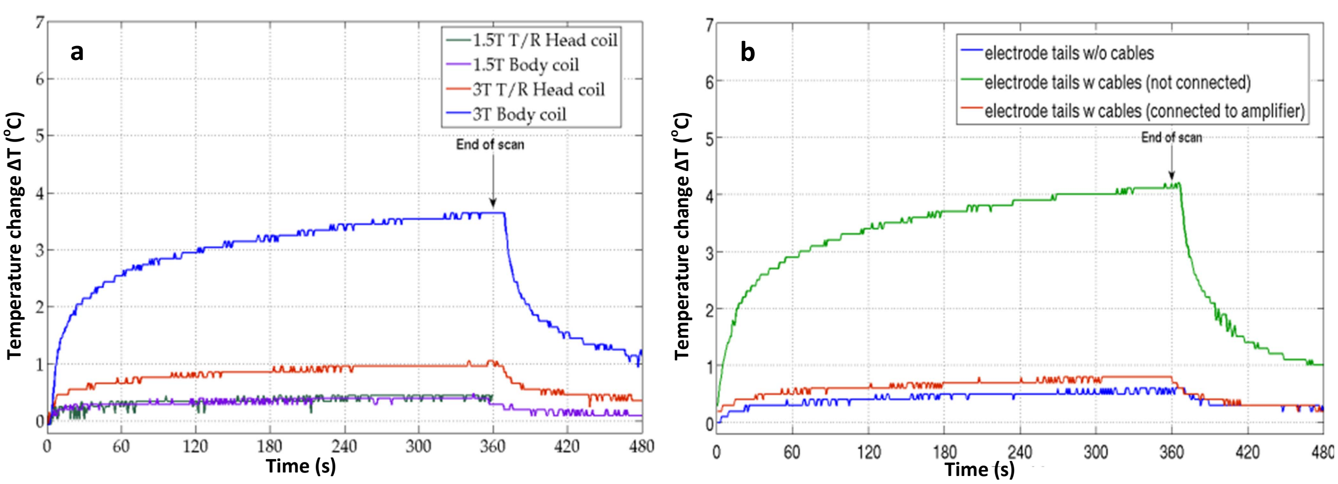

Figure 1: Temperature increase during a 3 W/kg SAR TSE sequence at the tip of SEEG electrode arranged parallel to B_0 for a) different magnet and coil combinations and b) different electrode tail terminations at 1.5T with transmit-receive head coil.

DISCUSSION /CONCLUSION: Heating observed using body transmit coil at 3T exceeded the guideline limits. Connecting the cables and varying the cable termination has a significant effect in RF-induced heating. However, in our specific set-up ΔT could be limited to safe levels by using a head transmit-receive coil and amplifier-terminated EEG cables, and by restricting sequence SAR. We recommend that scanner- and electrode-specific tests be performed.

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