Safety in simultaneous EEG-fMRI: temperature changes of the electrodes in a phantom and a volunteer study

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Simultaneous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) is a promising multimo-dal tool for studying the neurophysiology of the brain. In our hospital, an EEG-fMRI protocol is being developed to aid in the pre-surgical evaluation of patients with pharmacoresistant epilepsy. Introducing the EEG-equipment into an MRI envi-ronment requires specially designed MRI compatible EEG equipment, which are nowadays commercially available. How-ever, the safety of the equipment is guaranteed only for the functional studies and localizers [1]. To ensure the safety of the EEG equipment in the MRI environment for a wider range of sequences, they have to be tested before any clinical studies [2]. The purpose of this study was to explore one of the safety aspects, i.e. heating of the electrodes. Angelone et al. concluded in their simulation study that hot spots can not occur in the EEG-cap [3] and thus measuring a well distrib-uted sample of electrodes is enough to detect possible temperature rise.

The temperatures of the electrodes were measured, when the cap was placed on a phantom, and also a volunteer study was carried out. The volunteer study was approved by the local ethics committee and an informed written consent from the volunteer was obtained. A Brainproducts 64 channel EEG-cap (size 56) (BrainProducts, Munich, Ger-many) was chosen to be used in these measurements, because it is the most used cap for adolescent patients. In both cases the ECI electrogel (Electro-Cap International, Inc) was applied. The image acquisition was performed with a Philips Achieva 3T MR scanner (Philips Medical Systems, Best, The Netherlands) and a standard 8 channel Sense head coil was used. The temperatures of the electrodes were measured with an MRI compatible FISO 8 channel TMI system (FISO Technologies, Step. Foy, Quebec, Canada).

With the phantom, the temperature for all the electrodes according to the 10-20 layout were measured. For all the measurements one of the sensors were measuring the temperature of the air, so that the impact of the surround-ings could be taken into consideration. Two sequences were used: a 5 minute standard fMRI gradient echo echo planar imaging (GE-EPI) sequence with TR=3000 ms, TE=35 ms, EPI factor=79 and an estimated SAR of 0.511 W/kg, and a 5 minute T2-weighted Turbo Spin Echo (T2-TSE) sequence with TR=3756 ms, TE=75 and TSE factor= 15, Averages=2 and an estimated SAR of 3.2 W/kg.

For the volunteer study, the temperature for six electrodes (FP1, CPZ, O1, C5, FT8 and F4) was meas-ured. All the sequences that will be used in the future studies were included i.e. localizers; T1-weighted inversion recovery sequence as an anatomical reference image for the fMRI with TR=2580 ms, TE=15 ms, TI=400 ms, an in-plane resolution of 2 mm, slice thickness of 4 mm and an estimated SAR=2.2 W/kg ; T1 3D with TR=8.15 ms, TE=3,74 ms, isotropic voxel 1x1x1 mm³, multi-echo sequence for field map calculations with 2 echoes, TR=2530 ms, TE=35/70 ms and a esti-mate SAR of 1.9 W/kg, , Diffusion tensor with TR=8582 ms, TE=60, isotropic voxel 2x2x2 mm³, 32 diffusion sensitizing directions, b-value=800 and an estimated SAR of 0.9 W/kg; T2-TSE with TR=3756 ms, TE=75, TSE factor = 15 and an estimated SAR of 3.2 W/kg and the same fMRI GE-EPI-sequence as in the phantom studies

For the phantom studies a maximum temperature increase of 4.1º C in electrode FP2 was found for the T2-weighted TSE sequence. The mean temperature rise of all electrodes was 1.2 º C with standard deviation of 1.3º C. For the volunteer study the maximum temperature increase of 1.0º C , with a mean of 0.5º C and standard deviation of 0.3 º C was observed again for the T2-weighted TSE sequence. Only in the T1 IR-SE sequence image artefacts, degrad-ing the image quality in the brain itself, were observed.

For both the phantom and volunteer study the temperature increase was found to be at an acceptable level, because according to the manufacturer guideline the temperature has to be below 45º C [2]. A larger temperature increase was measured for the electrodes on the phantom than in the volunteer study. No clear correlation to the tem-perature fluctuations of the air was found. Previously, we have conducted two phantom and two volunteer studies in 3 Tesla with the same setup, but with different caps and electrode gels. These measurements resulted in a similar outcome.

In conclusion, the maximum temperature increase was found to be within safe limits to perform simultane-ous EEG-fMRI patient studies with our protocol in 3T.

[1] NEW BrainCap MR 32 and 64 Channel Standard Montages - Electrode Names & Numbers. Brain product leaflet
[2] BrainAmp Operating Instructions for the models BrainAmp Standard BrainAmp DC BrainAmp MR BrainAmp MR plus BrainAmp ExG BrainAmp ExG MR Version 012-B p 20-21
[3] Leonardo M. Angelone,* Andreas Potthast, Florent Segonne, Sunao Iwaki, JohnW. Belliveau, and Giorgio Bonmassar. Metallic Electrodes and Leads in Simultaneous EEG-MRI: Specific Absorption Rate (SAR) Simulation Studies Bioelec-tromagnetics 25:285^295 (2004)