Electroencephalography functional magnetic resonance imaging

EEG-fMRI (short for EEG-correlated fMRI or electroencephalography-correlated functional magnetic resonance imaging) is a multimodal neuroimaging technique whereby EEG and fMRI data are recorded synchronously for the study of electrical brain activity in correlation with haemodynamic changes in brain during the electrical activity, be it normal function or associated with disorders.

However, EEG data obtained from the simultaneous EEG-fMRI are strongly influenced by MRI-related artefacts, namely gradient artefacts (GA) and ballistocardiogram (BCG) artefacts. When compared to the GA correction, the BCG correction is more challenging to remove due to its inherent variabilities and dynamic changes over time. The standard BCG correction (i.e., average artefact subtraction [AAS]), require detecting cardiac pulses from simultaneous electrocardiography (ECG) recording. However, ECG signals are also distorted and will become problematic for detecting reliable cardiac peaks. In this study, we focused on a beamforming spatial filtering technique to attenuate all unwanted source activities outside of the brain. Specifically, we applied the beamforming technique to attenuate the BCG artefact in EEG-fMRI, and also to recover meaningful task-based neural signals during an attentional network task (ANT) which required participants to identify visual cues and respond accurately. We analysed EEG-fMRI data in 20 healthy participants during the ANT, and compared four different BCG corrections (non-BCG corrected, AAS BCG corrected, beamforming + AAS BCG corrected, beamforming BCG corrected). We demonstrated that the beamforming approach did not only significantly reduce the BCG artefacts, but also significantly recovered the expected task-based brain activity when compared to the standard AAS correction. This data-driven beamforming technique appears promising especially for longer data acquisition of sleep and resting EEG-fMRI. Our findings extend previous work regarding the recovery of meaningful EEG signals by an optimized suppression of MRI-related artefacts [1)].

Among 13 patients with focal epilepsy undergoing presurgical examinations including simultaneous EEG-fMRI at 3T, 11 patients had interictal epileptiform discharges (IEDs) during fMRI. The authors used the sequence of topographic maps during the IEDs as a reference to obtain subsecond fMRI activation maps with the same temporal resolution as the EEG data, and constructed “spike-and-slow-wave-activation-summary” (SSWAS) maps that showed the activation frequency of voxels during IEDs. Clusters were defined by thresholding the SSWAS maps (voxel value > 10), and those containing voxels with the top 3 highest activation frequencies were considered significant. Significant hemodynamic responses using conventional event-related (ER) analysis and SSWAS maps were compared with the resection areas and surgical outcomes at 1 year after surgery.

Using ER analysis, 4 (36%) of 11 patients had significant hemodynamic responses. One of 4 patients had significant hemodynamic responses in the resection area and good surgical outcome. Using SSWAS maps, 10 (91%) of 11 patients had significant hemodynamic responses. Six of 10 patients had significant hemodynamic responses in the resection area, and 5 of the 6 patients achieved good surgical outcomes. The remaining 4 patients had significant hemodynamic responses distant from the resection area, and only 1 of the 4 patients achieved good surgical outcomes. The sensitivity, specificity, positive predictive value, and negative predictive value of SSWAS maps were 83.3%, 75.0%, 83.3%, and 75.0%, respectively.

This study demonstrated the clinical utility of SSWAS maps for presurgical evaluation of pharmacoresistant focal epilepsy. The findings indicated that subsecond EEG-fMRI analysis may help surgeons choose the resection areas that could lead to good surgical outcomes [2].

1)

Uji M, Cross N, Pomares FB, Perrault AA, Jegou A, Nguyen A, Aydin U, Lina JM, Dang-Vu TT, Grova C. Data-driven beamforming technique to attenuate ballistocardiogram artefacts in electroencephalography-functional magnetic resonance imaging without detecting cardiac pulses in electrocardiography recordings. Hum Brain Mapp. 2021 Jun 8. doi: 10.1002/hbm.25535. Epub ahead of print. PMID: 34101939.

2)

Ito Y, Maesawa S, Bagarinao E, Okai Y, Nakatsubo D, Yamamoto H, Kidokoro H, Usui N, Natsume J, Hoshiyama M, Wakabayashi T, Sobue G, Ozaki N. Subsecond EEG-fMRI analysis for presurgical evaluation in focal epilepsy. J Neurosurg. 2020 Mar 13:1-10. doi: 10.3171/2020.1.JNS192567. [Epub ahead of print] PubMed PMID: 32168485.