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A multimodal approach to locate the STN electrodes in Parkinson disease patients

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Background:

The first aim of this study was to localize the electrodes in the sub-thalamic nucleus in Parkinson disease (PD) patients using the stimulation artifact during deep brain stimulation. The source analysis method used here is the dynamic imaging of coherent sources (DICS) (Gross et al. 2001) with a realistic boundary element method forward model (Fuchs et al. 2002). The second aim was to find out which of the modalities, electroencephalography (EEG), magnetoencephalography (MEG) or the combined approach is precise in estimating the localization of the electrodes.

Data and Methods:

The simultaneous EEG and MEG recording was done using an Elekta Neuromag system which consist of 306 MEG sensors and 60 EEG channels. The recording duration varied between 90 and 120 seconds in five PD patients. The parameters of the stimulating electrodes were according to the clinical setting of unipolar configuration for all the patients. The pulse width was 60 µs, the amplitude varied between (1.0 and 4.0 mA) and the frequency varied between (130 and 180 Hz). Power spectrum analyses were performed to identify the predominant stimulation frequency. The brain area with the strongest power in the analyzed frequency (130 or 180Hz) range was defined as the reference region. DICS was used to compute the coherence between this reference region and the entire brain. The source analysis was repeated for each of the modalities separately EEG, MEG and then the combined approach.

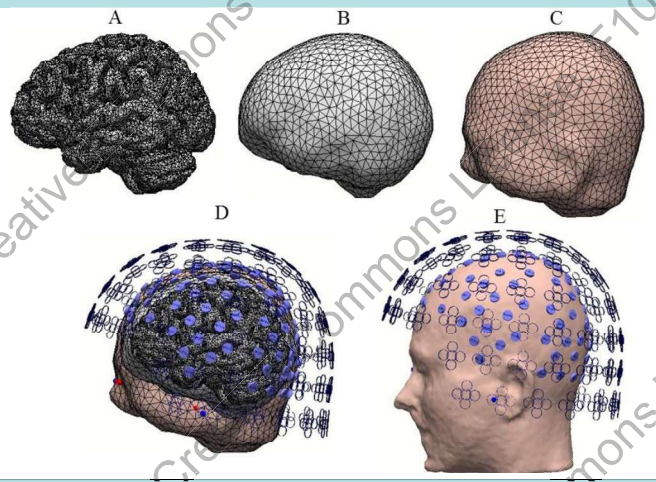

Figure 1: For a representative single subject the created realistic head model is shown. The layers are represented separately the brain (A), the skull (B), the scalp (C) followed by all the layers (D) with the interpolated electrodes and sensors on the scalp with transparent sections. (E) shows the location of the electrodes and sensors with respect to the subject's head.

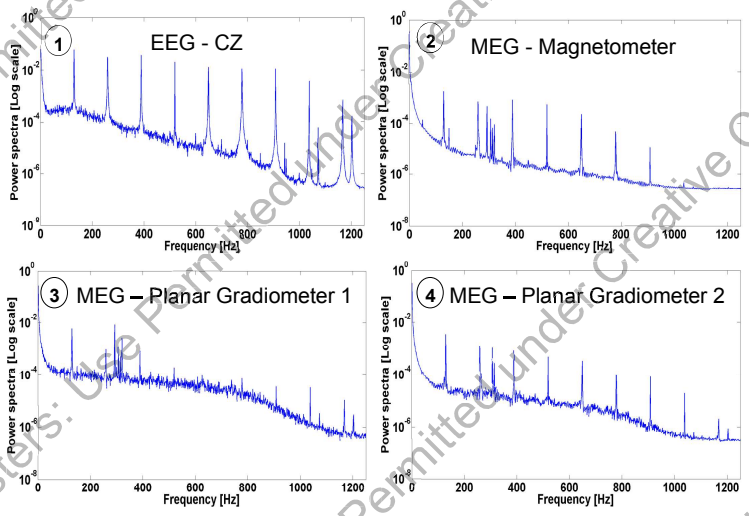

Figure 2: 1) Shows the power spectrum of the EEG channel-CZ. 2) Shows the power spectrum of an MEG Magnetometer. 3) Shows the power spectrum of the MEG channel Gradiometer 1. 4) Shows the power spectrum of the MEG Gradiometer 2.

Results:

The power spectral analysis on all the MEG/EEG sensors showed a clear peak at the stimulation frequency followed by its harmonics. The stimulation frequency source analysis in all the subjects was associated with bi-lateral sources in the primary motor cortex, pre-frontal cortex, secondary motor area, sub-thalamic nucleus, cerebellum and brain stem. The sub-thalamic nucleus was better localized by the combined approach in comparison to the EEG and MEG separately. The MEG spatial resolution was better compared to the EEG, however this could be due to the difference in electrodes and sensors. The spatial resolution was significantly higher in the combined approach; this was done by comparing the number of voxels activated between the three modalities. The coherence values were significantly higher in the combined approach to that of the individual modalities. The sub-thalamic nucleus grand average source in all the modalities is shown in figure 1.

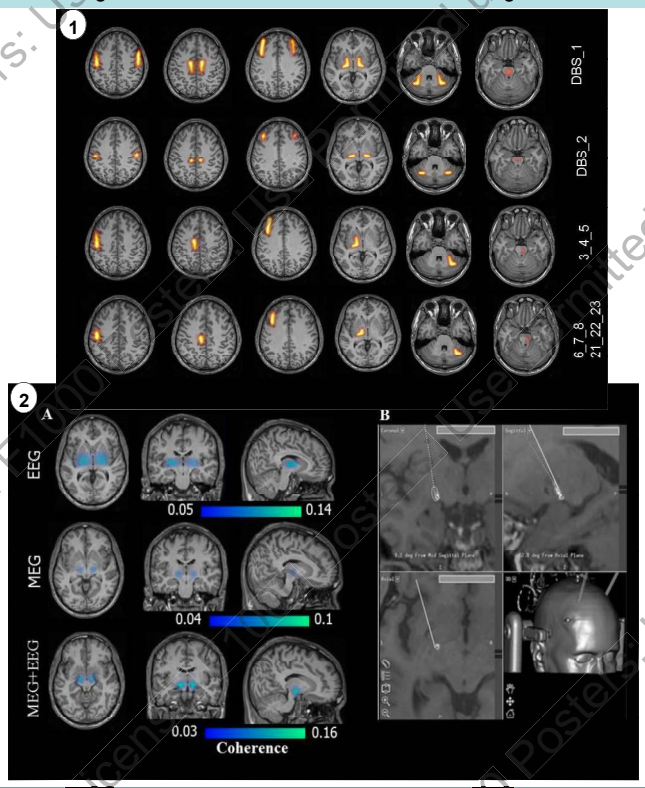

Figure 3: 1) Shows the grand average of the network of sources of all the patients for the different configurations during the deep brain stimulation. 2) Shows in detail the STN source for the three modalities with the reference figure of the STN needles from the representative patient.

Conclusion:

- The source analysis method was able to localize the sub-thalamic nucleus in all the patients using the artifact induced by the deep brain stimulation. The combined approach could be very efficient in localizing the electrodes in the sub-thalamic nucleus compared to the individual modalities. The localization of the electrodes is an excellent approach for the validation of the applied source analysis method and to test which is the best modality in such applications.

References:

Fuchs M, Kastner J, Wagner M, Hawes S, Ebersole JS (2002) A standardized boundary element method volume conductor model. Clin Neurophysiol 113 (5):702-712

Gross J, Kujala J, Hamalainen M, Timmermann L, Schnitzler A, Salmelin R (2001) Dynamic imaging of coherent sources: Studying neural interactions in the human brain. Proc Natl Acad Sci U S A 98 (2):694-699