Cluster-based Combined EEG/MEG Source Analysis of High Frequency Oscillatory Activity from a Multi-Focal Epilepsy Case

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***Abstract*—Almost 15 million of people are affected by pharmacoresistant epilepsy, a brain disorder that is treated with surgery when medicaments fail to suppress epilepsy seizures. The main goal in surgery is the identification and resection of the *epileptogenic zone (EZ)*, which is based on the doctor's experience. Recently, the high frequency oscillatory (HFO) epilepsy activity has been effectively used for the objective characterization of EZ. However, it remains unsure whether the HFO activity from combined Electro- (EEG) and Magnetencephalographic (MEG) – EMEG modalities can better localize the characterization of EZ. Here, we investigate the contribution of HFO activity on the indication of EZ with EMEG source analysis and individually calibrated skull-conductivity head modeling. A comparison with interictal spike-based source localization is performed.**

I. Introduction

Epilepsy surgery is the primary solution towards the restriction of EZ when the anti-epileptic drugs fail to suppress epileptic seizures. Non-invasive HFOs have shown similar or better accuracy on the indication of the EZ [1]. Non-invasive EMEG source analysis with individual skull-conductivity calibrated head modeling is a promising tool in presurgical epilepsy diagnosis and EZ localization [2]. Here, we compare EMEG source reconstructions using either interictal spikes or HFOs. The latter is coming from a new clustering approach to suppress the influence of false identified HFOs and facilitate source reconstruction. A patient with multi-focal epilepsy is analyzed in the study and the results are illustrated.

II. Methods

All the procedures took place after the written consent of the patient. Data was acquired from a 49-year-old female suffering from pharmacoresistant multi-focal epilepsy. Two focal cortical dysplasias (FCDs) were clinically detected, one in the right frontal area and one subtle in the left premotor cortex [2]. Anatomical characteristics were acquired from 3T Magnetic Resonance Imaging.

Spike detection was performed by well-trained epileptologists [2]. HFOs detection was performed based on the proposed pipeline given in (Fig. 1a). The first step for the EEG/MEG processing included filtering and artifact reduction. The implemented HFO detection algorithm was applied on the frequency spectrum, 80 to 500 Hz [2]. The algorithm engaged three steps; *1st step:* a thresholding technique applied on time domain, *2nd step:* visual inspection on time-frequency domain and *3rd step:* a k-means energy-based clustering approach on the detected HFOs. Clustering of HFOs aims on suppressing any false identifications and on grouping patterns with similar energy to facilitate source reconstruction. An averaging of HFO activity within each cluster was then performed, while all the annotated spikes were averaged to increase SNR. Consequently, sLORETA inverse source reconstructions based on sub-averaged HFOs and averaged spikes were performed to accurately indicate the FCDs. For both cases the same FEM forward computations were computed based on [3].

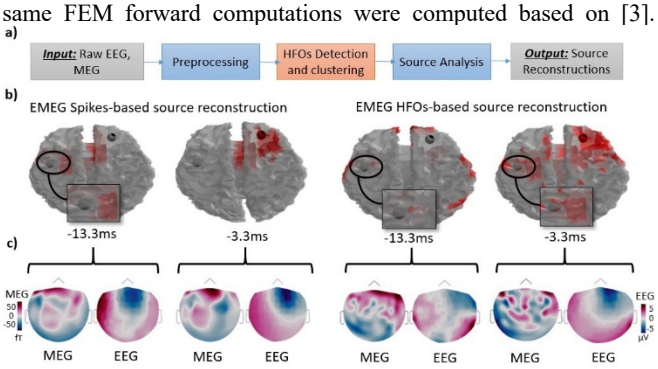

Figure 1. **EMEG HFOs and spikes-based source reconstruction**: **a)** The proposed pipeline for HFOs detection and source analysis **b)** The reconstructed source maps of EMEG source reconstruction based on spikes (left column) and HFOs (right column) at -13.3 ms and -3.3 ms for both cases. **c)** The corresponding topographies of MEG and EEG modalities. The black spheres represent the two FCDs as indicated in [1].

III. Results and Conclusion

In Fig. 1c, we observed the spikes-based source reconstruction at -13.3 ms (Fig. 1c) for which, MEG scalp topography shows source activity around the left FCD, while EEG scalp topography points in the central region of frontal lobe. This behavior was reflected in the corresponding source maps (Fig. 1b). At -3 ms, EEG scalp topography illustrated the maximum negativity around the right FCD, which was well-detected by EMEG (Fig. 1c, right column). HFOs-based source reconstruction revealed source activity in the vicinity of the left FCD and detected accurately the right FCD (Fig. 1c, left column). The EEG scalp topography (–3.3 ms) for the averaged spikes and subaveraged HFOs showed the maximum negativity on the right FCD. From our analysis, spikes and HFOs were capable of detecting the right FCD and also derived source activity in the vicinity of the subtle left FCD. The EMEG HFOs-based source reconstruction (-3.3 ms) reveals simultaneous epileptic activity at the left and right FCDs. Even though this time instance was almost the peak of the spikes and the SNR is high, spikes-based source reconstruction did not follow the same behavior.

We conclude that non-invasively HFOs and EMEG with calibrated head modeling can indicate multi-focal epilepsy lesions accurately.

References

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