Characteristics of Generalized Epileptic Discharges using duo ICA with Simultaneous EEG-fMRI

Clara H. Zhang, Zhiyi Sha, Yunfeng Lu, Thomas Henry and Bin He, *Fellow, IEEE*

SIMULTANEOUS scalp electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) have the combined strength of high spatial and temporal resolution. The aim of the present investigation is to use simultaneous EEG-fMRI to study both the electrophysiological and hemodynamic activities of an epileptic brain with generalized spike and wave discharges in a noninvasive fashion.

Epilepsy is one of the most prevalent and devastating neurological disorders. It affects about 0.6-0.8% of the population worldwide and causes staggering physical and economic burdens. Idiopathic generalized epilepsy (IGE) is characterized by spike and wave discharges that occur in a wide range of cortical areas. It is the most common type of discharges [1, 2]. One third of affected patients do not respond to anti-convulsive medication. Because of the wide range of areas affected, surgical resection cannot be performed. Consequently, for these patients treatment options are very limited. Therefore, a better understanding of the mechanism of generating generalized spike-wave discharges (GSW) is crucial for developing new therapies for patients with IGE. Currently it is postulated that a thalamocortical network is involved. The aim of this research was to use simultaneous EEG-fMRI to image GSW activities and elucidate the underlying mechanisms of this type of epilepsy.

Twelve epilepsy patients IGE were recruited. The study was approved by the Institutional Review Board of the University of Minnesota. 64-channel EEG signals were recorded in- and outside of the MR scanner. A separate out-scanner EEG was collected, from which the timings of the GSW discharges were confirmed by trained epileptologists. Spatial characteristics of the GSW discharges in the sensor space from out-scanner EEG were used as the baseline template. Temporal and spatial Independent Component Analyses (ICA) [3, 4] were applied to the concurrent EEG and fMRI respectively. Independent components of the functional MRI data that were temporally correlated to the expected time course were chosen as epilepsy related component. Seed based temporal correlation was also calculated by selecting regions, including thalamus, that were hypothesized to be involved in generating GSW discharges.

In the twelve patients studied, seven had GSW discharges. In three patients, thalamus was found to be temporally correlated to other cortical regions such as the default mode network or sensorimotor or occipital cortex, which was consistent with previous reported findings [1, 2, 4-6]. In five patients, BOLD components associated with default mode networks were found to have an altered spatial distribution. Individual patients had spatial patterns of the default mode network that deviate from the symmetrical bilateral fronto-parietal pattern. These patients had coactivation of the unilateral frontal areas or absence of activity in the parietal region. In two out of the seven patients, both the involvement of thalamus and unilateral changes of the default mode network were observed.

Simultaneous EEG and fMRI were employed to study brain generators of GSW discharges. Our findings suggested an altered default mode network and the involvement of thalamus in generating GSW discharges. The proposed duo ICA frame work can be used to further investigation the neurovascular coupling in epileptic brains on a broader population.

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