Functional Connectivity Network during Seizure: A Comparative Study on Phase Synchronization Measures

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***Abstract*— The functional connectivity network (FCN) of brain can be measured by using phase synchronization (PS) of a pair of EEG channels. We compare two methods for measuring PS. Results show that our proposed measure based on the correlation between probabilities of recurrence (CPR), outperforms a conventional frequency-domain measure and shows statistical difference in all morphological seizures.**

I. Introduction

Electroencephalography (EEG) is considered an important biometric for the diagnosis and screening of epileptic seizure detection. Typical recurrent waveforms often exist in seizure EEG signals. Such morphological patterns often affect seizure detection performance [1] and may also correspond to different functional connectivity networks (FCNs) of brain systems [2]. The analysis on dynamic FCNs in seizures can be useful for seizure detection and localization.

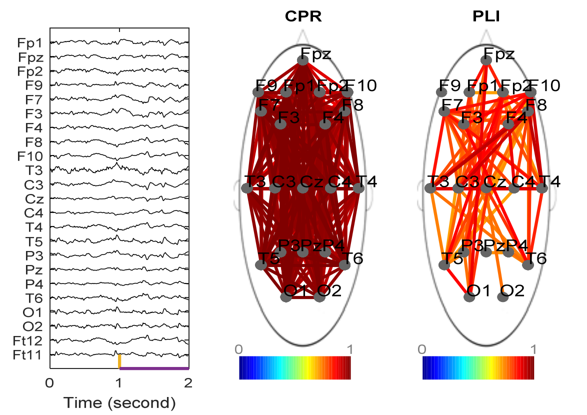

Figure 1. FCNs measured by using CPR and PLI. The corresponding 2 s EEG epoch (left) is the onset of a seizure with spike-wave morphology.

II. Data and Methods

Intellectual disability (ID) is one of the most common secondary disabilities in people with epilepsy. We used 24-channel scalp EEG signals from 8 epilepsy patients with ID, including 24 seizure events (accumulated 1414 seconds) and interictal EEG segments before each seizure (accumulated 24 mins). We started from four predefined seizure morphologies: (1) fast spike, (2) spike-wave complex, (3) wave, and (4) seizure-related electromyography (EMG) artifacts. FCN of brains can be constructed by using the phase synchronization (PS) between each pair of EEG channels. We compared two different methods of measuring PS. One is the traditional phase lock value/index (PLI) [3] in the frequency domain. The other is a new method from chaos theory, named correlation between probabilities of recurrence (CPR) [4]. It is a nonlinear recurrence measure of the synchronization of chaotic systems (i.e., nonlinear dynamical system). We studied the dynamic FCNs of seizures, where each 2-sec epoch (including 24 channels EEG) is used to compute a temporary FCN by using PLI and CPR, respectively (as shown in Fig.1). By averaging all the connections in a FCN, we obtain the average connecting strength (ACS). We statistically compare ACS between seizure and non-seizure epochs.

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III. Results

For each seizure pattern, we pooled over all the seizure and non-seizure epochs from a number of seizure events. A t-test was used to evaluate the increment of ACS after seizure onset. Table 1 shows that CPR-based ACS show statistical difference after seizure onset in all seizure patterns while PLI-based ACS show no significant change in seizures with spike-wave and wave patterns.

TABLE I. Statistical results of ACS on EEG epochs

Seizure pattern	No. of seizures	Accumulated time (s) of EEG epochs		Increment of ACS (t-test)*	
		Non-seizure	Seizure	**CPR**	**PLI**
Spike	8	480	88	-0.17	+0.09
Spike-wave	6	360	114	+0.14	#
Wave	6	360	747	+0.05	#
EMG	4	240	465	-0.46	+0.16

* denotes the increment of ACS is not zero ($P < 0.00001$) except #.
'+/ -' denote normalized increment [-1 +1] of mean ACS from non-seizure to seizure epochs.

References

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