Detecting Electrodes Leading to Seizure from Subdural EEG via Spectral Phase Analysis

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1 Abstract

This paper presents preliminary findings on phase information extracted from the spectrum of subdural EEG signals prior to seizure onset. EEG data files of 300 seconds duration from eight children with medically refractory partial seizures that underwent pre-surgical evaluation were divided into consecutive time windows to extract the phase of the spectrum. The analysis revealed that the phase plot of most electrodes leading to seizure narrows and shows a positive trend in the second half of the spectrum, whereas this behavior could not be observed in any of the electrodes not leading to seizure.

2 Introduction

The EEG of epileptic subjects can be divided into two main categories, interictal and ictal. The interictal EEG is the EEG taken when the patient is not having seizures or in between seizures [1]. The EEG interictal data recorded inside the brain can be processed to define similar patterns evident in those electrode trails that lead to a given seizure to further facilitate surgical planning [2]. Interictal activity is considered to be abnormal if it can occur in a patient with epilepsy without the occurrence of an actual seizure. The ideal EEG activity on the other hand is when the actual seizure occurs. To date, much research has been done to study the behavior of interictal EEG data and classify electrodes [3, 4, 5, 6, 7]. This study proves that electrodes leading to an epileptic seizure can be detected by applying the phase of the spectrum of ictal and interictal EEG files. The main objectives were as follows (1) to compute the spectrum of EEG recordings, electrode by electrode; (2) to establish mathematical derivations that provide not only quantitative measures, but also locate the focus of an ictal activity (3) to identify and formulate the patterns in EEG recordings that are inherent to those electrodes that lead to a seizure; (4) to correlate the clinical features with the EEG findings in order to determine whether the patient has a consistent source of ictal activity, which is coming from the location concerning the group of channels that present interictal activity; (5) to classify and to group those EEG channels that are known in advance to lead to seizures in order to extract similarities in their behavior, so as to find common behavioral patterns.

3 Methods

Participants

8 children with medical refractory partial seizures that underwent pre-surgical evaluation.

Methodology

- The spectrum of the EEG recordings was computed for each channel. Input data were EEG segments of 300 seconds duration of epileptic patients. For each spectral file, the phase was computed as the arctan between the real and the imaginary part of the spectrum.
- After plotting the phase of each window for each channel, a shrinking of the phase plot was observed in the last 4th portion of the frequency spectrum for most of the windows in the ictal EEG channels. Therefore, the classification algorithm consisted of developing a pattern extraction procedure to recognize the shrinking of the phase plot for that particular frequency range. The steps were as follows: (1) Preparation and normalization of ictal EEG file, (2) Computation of the frequency spectrum of the EEG recordings, (3) Extraction of the phase from the spectrum, (4) Extraction of a feature in the phase domain to measure the plot shrinking.
- In step (1), the ictal EEG files were cut such that all of them extend only over the last 5 minutes immediately before the seizure. We had the precaution to remove the seizure part from the file, so as to avoid misleading patterns to bias the analysis.
- In step (2), the spectral files were computed piecewise for successive, non-overlapping time windows of 8 seconds duration.
- The plot in Fig. 1 shows how the phase plot narrows for window #15 (3 minutes before onset of seizure 1) for electrode #2, which leads to seizure. The narrowing is very pronounced in the last half of the frequency band. Fig. 2 shows the same plot for an electrode that does not lead to seizure (electrode #1) at the same time window. This behavior could be observed in most of the electrodes leading to seizure whereas the narrowing does not always begin in the second half. Some electrodes presented a narrowing in the last 4th portion of the spectrum.

4 Results

- Since not all windows of the electrodes leading to seizure presented the phase narrowing, the STD of the last 4th portion of the phase plot was plotted for each window, as is shown in Fig. 3 for a specific seizure file. On the left, the plot of the phase STD of the electrodes leading to seizure (2, 3, 5, 10, 18, 20) is visualized. The right panel shows the corresponding plots for some of the electrodes not leading to seizure (1, 4, 6, 7, 8, 9). A comparison of the two column plots clearly shows that the area under the plot is higher for the right column than for the left column plots. This fact was also observed in the remaining 4 seizure files from the same patient.

5 Discussion

- The contribution of our study is to understand better the characteristics of the different interictal epileptiform activities. In all electrodes analyzed, it could be proved that the phase plot narrowing in time is only possible if the electrode leads to seizure, whereas no plot narrowing was observed for the remaining electrodes.
- These findings allow for a better understanding of the dynamics of the brain in terms of how spectral analysis can be used to detect and ultimately predict epileptic seizures.

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7 References

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