Time-variant connectivity pattern estimation during multiple epileptic seizure onsets

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I. Introduction

Epilepsy is a neurological disorder characterized by recurrent seizures, i.e. abnormal synchronous activity of neurons in the brain. The brain region responsible for the epileptic activity is called the epileptogenic region. In most cases epilepsy can be cured by using anti-epileptic drugs. However, approximately 25% of the patients cannot be cured through medication or by medical treatment, they suffer from so-called refractory epilepsy. This can be treated by surgically removing the epileptic focus. The possibility for this surgery is examined during the presurgical evaluation [1]. Therefore, the precise and accurate location of the epileptic region is of utmost clinical relevance.

Intracranial ElectroEncephaloGraphy (iEEG) is the recording of brain activity at a high temporal resolution through electrodes placed within the brain and is used to help locating the epileptic focus during the presurgical evaluation. Functional connectivity estimates the statistical dependence between spatially remote neurophysiological events and provides insight about the propagation pattern of information flow between signals. The aim of this study is to identify and detect the functional connectivity pattern through iEEG-analysis during multiple epileptic seizure onsets of the same patient to locate the epileptic focus more accurately.

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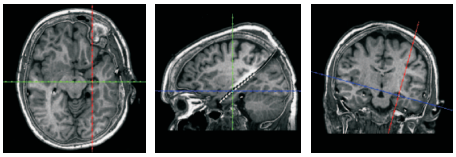

Figure 1. Placement of the intracranial electrodes

II. Data and Method

A. Data

We considered EEG epochs of approximately 15 to 20 seconds during 10 different seizure onsets. The signals were recorded with an intracranial depth electrodes with 12 contact points (LH1 to LH12) located in the left hippocampus. Pre-surgical evaluation indicated seizure onset at LH4-LH5. The placement of the intracranial electrode in the brain is showed in figure 1.

B. Method

The method determines the functional connectivity pattern of the recorded signals during 10 different seizure onsets. A measure to express functional connectivity is the Directed Transfer Function (DTF) [2] which is calculated from the coefficients of a multivariate autoregressive (MVAR) model fitted to the signals [3]. The DTF reveals the information flow from one signal to another at a specific frequency by exploiting statistical dependencies within the multichannel iEEG recordings. However, this DTF requires that the signals are stationary over the assumed time-window.

In order to take into account the non-stationarity of the epileptic seizure a time-

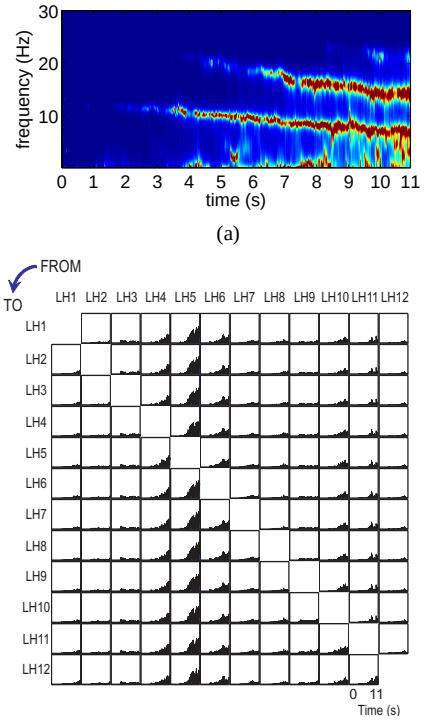

Figure 2. Results of one seizure. (a) Energy described by the TVAR model and (b) Functional connectivity values

variant multivariate autoregressive (TVAR) model with time-varying parameters was fit to the data. The coefficients of the TVAR model were derived using the Kalman filtering algorithm [4]. A time-variant version of the DTF, the Adaptive Directed Transfer Function (ADTF), was constructed out of the coefficients of the TVAR model. The ADTF shows the information flows between the signals in the frequency domain as a function of time.

The energy captured by the TVAR model was calculated by summing the ADTF values over all channels at each frequency and at each time point. The sum of the normalized ADTF values over the frequencies with the highest energy was calculated. This value maps the functional connectivity of the most important frequencies over time.

III. Results

We applied the method to 12 iEEG signals recorded during 10 seizure onsets of the same patient. The result of one seizure is depicted in figure 2.The fundamental frequencies of the seizure as well as its harmonics can be seen in the energy captured by the TVAR model. The functional connectivity values show that information flow is going from LH5 to all the other signals. We found that the same region (LH4, LH5 and LH6) was responsible for the spreading of epileptic activity during all 10 different seizure onsets. Furthermore, the leading region was concordant with post-operative results.

IV. Discussion and Conclusion

The results show that the explained method is capable in locating the epileptic focus through the analysis of iEEG signals for this patient. We proved that connectivity patterns derived from iEEG recordings can provide useful information about seizure onset propagation and may improve the accuracy of the presurgical evaluation. However, more patients need to be examined to evaluate the proposed method.

References

[1] P. Boon, T. Vandekerckhove, E. Achten, E. Thierry, L. Goossens, K. Vonck, M. Dhave, G. Van Hoey, B. Vanrumste, B. Legros, L. Defreyne, and J. De Reuck, "Epilepsy surgery in belgium, the experience in gent," *Neurologica Belgica*, vol. 99, pp. 256–265, 1999.

[2] Maciej Kaminski, Mingzhou Ding, Wilson A. Truccolo, and Steven L. Bressler, "Evaluating causal relations in neural systems: granger causality, directed transfer function and statistical assessment of significance," *Biological Cybernetics*, vol. 85, pp. 145–157, Aug. 2001.

[3] Lennart Ljung, *System Identification: Theory for the User*, Prentice Hall, 1999.

[4] M. Arnold, X.H.R. Milner, H. Witte, R. Bauer, and C. Braun, "Adaptive ar modeling of nonstationary time series by means of kalman filtering," *Biomedical Engineering, IEEE Transactions on*, vol. 45, pp. 553–562, 1998.