Chaos analysis of electro encephalography and control of seizure attack of epilepsy patients

T. Yambe a,*, E. Asano b, S. Mauyama c, Y. Shiraishi a, M. Shibata a, K. Sekine a, M. Watanabe a, T. Yamaguchi a, M. Shibata a, T. Kuwayama a, S. Konno a, S. Nitta a

a Department of Medical Engineering and Cardiology, Institute of Development, Aging and Cancer, Tohoku University, 4-1 Seiryo-machi, Aoba-ku, Sendai 980-77, Japan
b Children Hospital of Michigan, Wayne University, Wayne, USA
c Institute of Fluid Sciences, Tohoku University, Tohoku, Japan

Abstract

In order to evaluate the EEG of patients with epilepsy, chaos analysis was performed for the subdural EEG time series data. The chaos attractor was reconstructed in the phase space and the correlation dimension. KS entropy calculated from the Lyapunov exponents was evaluated. Before the seizure attack, the KS entropy showed a lower value when compared with the time series data recorded during healthy condition. The results of our study suggest that it is possible to predict the seizure attack by the chaos analysis of the EEG signal. Further, we aim at developing an automatic control system for predicting a seizure attack by the use of local cooling of the focus with Peltier elements.

Keywords: EEG; Epilepsy; Chaos; KS entropy; Peltier elements

1. Introduction

The convulsions in epilepsy indicate a poor patient prognosis. Approximately 0.5–1.5% of the general population of the world has epilepsy [1-5]. Seizures cannot be controlled by medication alone in 20% of the epilepsy patients. Some epilepsy patients can be treated by surgical operation [5-10]. In a brain surgery operation, the determination of the excision boundary is important. If the excision range is large, a functional disorder of the nerve may occur. Furthermore, epilepsy may not be cured if the excision range is very small.

PET, CT, MRI, positron CT, and EEG are important examination techniques. Recently, subdural EEG records have been obtained using the implantable-type electrodes in the state of awakening. Further, it is possible to obtain a continuous EEG record at the time of an epileptic convolution [11-15]. It is also possible to record the site of the origin of the wave at the beginning of epilepsy. Therefore, this improves the accuracy of surgeries.

In this study, we attempted chaos analysis of the EEG time series data by continuous subdural recording.

2. Materials and methods

The patient used in this study is a 2-year-old boy with epilepsy. Subdural EEG electrodes were implanted to record the EEG during the seizure attack in order to determine the resection area of the surgery and reduce the seizure attacks.
The evaluation algorithm employed for EEG was Sunday Chaos Times developed by Aihara Co. In this study, novel strange attractors were reconstructed in the phase space from the time series data and the correlation dimension and KS entropy from Lyapunov exponents was calculated.

3. Results

The pattern of the EEG signal at the focus was found to be significantly modified before the seizure attack. The time series data of the EEG signal was embedded into the phase space using the analyzing program, as shown in Fig. 1. This figure also shows the attractor that was obtained from the time series data without seizure attack.

The attractor obtained from the time series data of the EEG before the seizure attack is shown in Fig. 2. Lyapunov exponents analysis of the reconstructed attractor, KS entropy evaluation, and correlation dimensional analysis suggested the simplification of the nonlinear dynamical behavior before the seizure attacks.

4. Discussion

As shown in the results of this study, the EEG wave pattern was found to be significantly modified before the seizure attack. Particularly, the EEG wave before the epilepsy attack was analyzed by the chaos theory. As a result, the simplification of an attractor is observed before an epilepsy attack. The simplification of an attractor was quantified based on the Lyapunov exponents and correlation dimension. Quantitative results suggest that the KS entropy decreased before the epilepsy attack. EEG signals were influenced by the nonlinear dynamical behavior of the central nervous system. It is very interesting when we consider the modifications of the nonlinear dynamics before the seizure attack.

Based on these results, it may be possible to predict an epilepsy attack by the chaos analysis of EEG. Furthermore, it may also be possible to determine the excision range of a brain surgery by the chaos analysis of EEG.

We intend to add new cases to advance our existing research.

Several investigators have suggested that a seizure attack can be controlled by local cooling [16–18]. Based on previous studies, we have developed a novel seizure-control implantable device (Japan Patent No. 2004-304964). This device is expected to be available in the market in the near future.

Acknowledgements

This work was partly supported by a grant-in-aid for Scientific Research (11480253), the Program for Promotion of Fundamental Studies in Health Science for Organizing Drug ADR Relief, R&D Promotion and Product Review of Japan, Research on Advanced Medical Technology in Health, and Labor Sciences Research Grants (H14-Nano-020), Research Grant from Fukuda Memorial medical Technology Promotion Foundation, Research Grant from Nakatani Electronic Measuring Technology Association of Japan, Research Grant from The Japan Epilepsy Research Foundation and Research Grant from Center for Interdisciplinary Research, Tohoku University and 21 COE program of Tohoku University.

References


