Automated Seizure Prediction Algorithm and its Statistical Assessment: A Report from Ten Patients*

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Summary. The ability to predict epileptic seizures well prior to their clinical onset provides promise for new diagnostic applications and novel approaches to seizure control. Several groups of investigators have reported that it may be possible to predict seizures based on the quantitative analysis of EEG signal characteristics. The objective of this chapter is first to report an automated seizure warning algorithm, and second to compare its performance with other, theoretically sound, statistical algorithms. The proposed automated seizure prediction algorithm (ASPA) consists

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of an optimization method for the selection of critical cortical sites using measures from nonlinear dynamics, and a novel method for the detection of preictal transitions using adaptive transition thresholds according to the current state of dynamical interactions among brain sites. Continuous long-term (mean 210 hours per patient) intracranial EEG recordings obtained from ten patients with intractable epilepsy (total of 130 recorded seizures) were analyzed to test the proposed algorithm. For each patient, the prediction ROC (receiver operating characteristic) curve, generated from ASPA, was compared with the ones from periodic and random prediction schemes. The results showed that the performance of ASPA is significantly superior to each naive prediction method used (p-value < 0.05). This suggests that the proposed nonlinear dynamical analysis of EEG contains relevant information to prospectively predict an impending seizure, and thus has potential to be useful in clinical applications.

**Key words:** Epilepsy, Dynamical entrainment, Automated seizure prediction, Naïve prediction schemes, ROC curves.

1 Introduction

Epileptic seizures result from a temporary electrical disturbance of the brain and affect at least 50 million people worldwide, including 1.4 million Americans. For the patients with epilepsy, the occurrences of seizures interfere with their normal life and are sometimes fatal. One of the most disturbing aspects of epilepsy is that the occurrences of seizures appear to be random and unpredictable. Therefore, seizure prediction is listed as one of the most important future directions in epilepsy research [13]. The ability to predict epileptic seizures well prior to their occurrences provides promise for new diagnostic applications and novel approaches to seizure control. Therefore, any methods that can reliably predict or warn of a seizure occurrence would be very clinically significant. An immediate application of such an automatic seizure prediction computer algorithm, incorporated into existing long-term EEG recording equipment, could be used for diagnostic purposes and to enhance patient safety and treatment by alerting the nursing and technical staff of impending seizures.

Several groups of investigators have reported that it may be possible to predict seizures based on analysis of the EEG signal characteristics. For example, Lasemidis and coworkers use $STL_{\text{max}}$ to detect preictal state prior to seizure onset [5, 11, 12, 21]; Lehnertz and Elger [3, 14] use the effective correlation dimension to detect a change in dynamics before a seizure; Martinerie and coworkers [16, 18, 19] apply dynamical similarity analysis to show significant difference between preictal and interictal states; Litt and coworkers [15] reported that number of energy bursts starts increasing several hours prior to seizure onset. Most recently, Mormann, Andrzejak and coworkers [17] showed that the period preceding a seizure can be characterized by a decrease in syn-