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EEG entropies as estimators for the diagnosis of encephalopathy

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Abstract

Brain consists of a network of millions of neurons and the neural activities of the brain are clearly pictured in its signal, electroencephalogram (EEG). Many pathological conditions of brain can be studied in detail by inspecting the EEG signal in detail rather than just visual inspection. Non linear analysis has proved to be an efficient method for exploring the subtle information embedded in EEG. Approximate entropy and sample entropy are utilized in this study for comparing EEGs of patients with a neurological disease called encephalopathy, with normal EEGs. Both entropies were found to be significantly less ($p < 0.01$; independent sample t test) for encephalopathy group than normal healthy controls. Support vector machine, multilayer perceptron and random forest classifiers have been employed for identifying disease groups based on the EEG entropies and their performance were evaluated. Random forest classifier gave the maximum accuracy of 90% while multilayer perceptron and SVM classifier gave an accuracy of 87% and 84% respectively. The optimum performance was obtained by combining both approximate entropies and sample entropies as features to the classifiers, than using individual set of features. Thus, this work emphasizes that entropies of EEG are good bio-markers for the diagnosis of encephalopathy and that non linear analysis techniques should be employed for analyzing EEG signals.

Keywords EEG · Encephalopathy · Approximate entropy · Sample entropy · Random forest classifier · Multi-layer perceptron classifier · Support vector machine classifier

1 Introduction

Encephalopathy is a disease state in which higher brain activities are affected due to metabolic disturbances. Metabolic encephalopathy is characterised by the general deterioration in the brain functioning caused due to failure of major organs of the body like liver, kidney or due to electrolytic imbalances [1]. Encephalopathy caused due to acute or chronic renal failure is termed renal or uremic encephalopathy. Encephalopathy caused due to liver dysfunction or due to liver disease like hepatitis or cirrhosis is called hepatic encephalopathy [2]. Encephalopathy due to low level of sugar in the blood is hypoglycaemia. Thus, cerebral activity is affected in metabolic encephalopathy in the absence of gross structural abnormalities of the brain [3, 4]. Thus, it can be considered as a secondary neurological disease as brain is not primarily affected in this disease.

EEG, being the brain signal is extensively studied for the diagnosis of various neurological diseases. In encephalopathy, background slowing and slow wave activities are noted in EEGs. In 1950, Foley et al. [5] reported high voltage slow waves of patients with hepatic encephalopathy in coma state. Many studies later demonstrated triphasic waves as a pattern in EEG of hepatic encephalopathy though they are non-specific in nature [6, 7]. Triphasic patterns which are observed in various types of metabolic encephalopathies, are high-amplitude (70 μV) positive sharp transients that are preceded and followed by negative waves of relatively lower amplitude [8]. Faigle et al. [9] emphasised the need for more specificity for EEG—based diagnosis of encephalopathy. The motivation of this study is to identify the discriminating features in EEG for diagnosing encephalopathy based on non-linear analysis.

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