Wavelet and multifractal estimation of the intermittent photic stimulation response in the electroencephalogram of patients with dyscirculatory encephalopathy

O.E. Dick*, I.A. Svyatogor

Laboratory of Physiology of Reception, Pavlov Institute of Physiology of Russian Academy of Science, nab. Makarova, 6, 199034 St. Petersburg, Russia

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A B S T R A C T

The task is to elucidate quantitative characteristics in electroencephalographic (EEG) patterns giving the possibility to estimate the disruptions of the functional state of the central nervous system caused by dyscirculatory encephalopathy of different severity. For solving the task the background and reactive EEG patterns are analyzed by the continuous wavelet transform and the wavelet-transform modulus maxima methods. The EEG responses to intermittent photic stimulation are used as reactive patterns. There are no statistical differences between the width of the singularity spectra of background and reactive patterns for all the subjects. Therefore, the degree of multifractality determined by this parameter does not change considerably during the photic stimulation. By contrast, the coefficients of photic driving and holding and the energy increase times gained in EEG patterns of patients with dyscirculatory encephalopathy differ significantly from the parameters determined for the healthy subjects. The reactive patterns have been demonstrated to have the different photic driving of beta, theta and alpha ranges for the patients of various groups. Frequencies of the theta range are reproduced mainly in the EEG patterns of patients with hypertension disease and with vertebrobasilar insufficiency. The maximal photic driving reaction of the beta range is noticed in the group with the vegetovascular dystonia. Frequencies of the alpha range are predominantly reproduced by the group with hypertension disease. The study demonstrates the opportunity to estimate quantitatively the dynamics of changes in energy characteristics of EEG patterns for various groups of patients having cerebrovascular disturbances. The results can be applied for an appropriate choice of treatment for such patients with the regard for their photic driving reactions.

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1. Introduction

Bioelectric activity of the human brain recorded from the head surface as electroencephalography (EEG) time series reflects non-stationary dynamics of synchronized and unsynchronized relations between large neuron ensembles [1]. The comparative analysis of this dynamics is a possible tool for elucidating the degree of the brain seizures [2–4] or for estimating the drug or psychotherapeutic treatment efficiency [5]. Sometimes elucidation of changes in EEG patterns is a rather complex problem. For example, it is difficult to distinguish the diffuse neuronal activity arising as a late effect of traumatic brain injuries, neuroinfections or cerebrovascular disturbances from the normal one. Notice that such disorders are much more typically in clinical practice than severe brain tissue damages. Organic lesions of the brain lead as a rule to well detectable local disruptions and paroxysmal forms of EEG [6]. There is no such specificity in EEG patterns of the diffuse activity [7]. It forces investigators to search new analytic methods [8,9]. In this connection, the concept of the functional state of the central nervous system and its features such as excitability, lability and stability assumes great importance [10].

To identify changes in the functional state clinicians use the functional probe as photic stimulation since sometimes variations in background EEG break down to reveal the changes. For example, in geriatric clinical work, only the decreased driving reaction differentiated the patients suffering from early dementia from age-matched depressed ones, whereas the resting EEG did not show any differences [11]. Intermittent photic stimulation can induce a phenomenon of photic driving in EEG patterns as a normal physiologic response triggered by specific visual stimuli [12]. The response, as a rule, is time-locked to the light stimulus at a frequency that identical or harmonically related to the frequency of light flashes [13]. Photic stimulation is applied for determining the human brain lability to reproduce or to reject the suggested
The degree of such lability can characterize the level of nerve excitability [15]. For non-paroxysmal responses to intermittent photic stimulation, cortical lesions of a destructive type may cause ipsilateral depression or attenuation of driving, whereas irritative lesions, such as those of epileptic scars, may lead to an increased response on the side of a hypersynchronized response within the alpha band may re...
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