Wearable Multimodal Analyzers in the Microcirculatory-Tissue Systems Monitoring During Different Sleep Stages

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Abstract— This paper presents the first results of the study of changes in microcirculatory-tissue systems functioning during different sleep stages.

Keywords— somnology, laser Doppler flowmetry, fluorescence spectroscopy, wearable analyzers, sleep, microcirculatory-tissue system

I. Introduction

The active development of society, cognitive load and an high level of stress lead to the emergence of various somnological disorders. One of the most common disorders is insomnia, which effects from a third to half of the world's population. Sleep disorders lead to increased fatigue, decrease productivity, and in the long term to the development of diseases of the cardiovascular, immune and endocrine systems of the body. Thus, sleep disorders are an acute medical, social and economic problem of our time, therefore it is important to improve the methodology of sleep monitoring. In somnology, the work of the brain during sleep is actively studied, however, little attention is paid to the peripheral part of the cardiovascular system - the microcirculatory-tissue systems (MTS) of the human body [1], which was the work purpose.

II. Materials and Methods

Special protocol was developed for long-term MTS monitoring with wearable multimodal devices "LAZMA PF" (LAZMA Ltd, Russia; in EU/UK this device is made by Aston Medical Technology Ltd., UK as "FED-1b") and simultaneous registration of electroencephalography (EEG) by Neuron-Spectrum-3 (NEUROSOFT, Russia). These analyzers implement optical noninvasive diagnostic methods for recording peripheral blood flow parameters by laser Doppler flowmetry (LDF) and oxidative tissue metabolism by fluorescence spectroscopy (FS) [1].

Two wearable devices were fixed symmetrically to the right and left on the palmar surface of the proximal phalanges of the third fingers. Measurements were carried out on 3 volunteers (20-24 years old) during a night's sleep for 4-7 hours, the total data was obtained for 5 sleeps. Based on EEG, 4 sleep phases were distinguished: NREM 1 (stage 1 sleep), NREM 2 (stage 2 sleep), NREM 3 (slow-wave sleep), REM (rapid eye movement sleep) and wakefulness.

III. Results

The analysis of pilot data showed that the change of sleep phases is characterized by a change in the average level of skin perfusion. At the same time, in the morning there is a decrease in the normalized amplitude of NADH fluorescence, which indicates an increase in the activity of oxidative metabolism. During REM sleep, the modulation of blood flow by active regulatory mechanisms significantly increases, which is confirmed by an increase in the amplitudes of endothelial, neurogenic and myogenic oscillations (statistically significant difference was confirmed by Mann-Whitney U-test, $p < 0.05$). The results obtained correlate with the available information on the activation of sympathetic system during REM sleep [2]. It is worth noting that the MTS parameters (normalized amplitude of NADH fluorescence, standard deviation and amplitude of endothelial oscillations normalized to index of microcirculation) showed the possibility of separating sleep phases without EEG.

Thus, thanks to the use of LDF and FS in combination with EEG it is possible to obtain additional information about the functional state of the MTS of the human body during sleep stages, which will allow a comprehensive study of somnological disorders and evaluate the effectiveness of their therapy.

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