FEATURES OF THE FUNCTIONAL STATE OF THE BRAIN IN PATIENTS WITH POST-COVID SYNDROME

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Abstract: Seventy-six patients with post-COVID syndrome were examined using the electrophysiological method. Electroencephalography (EEG) analysis was used as an electrophysiological technique. Patients differed from healthy people by subjects in significantly lower values of the spectral power of the alpha rhythm in the occipital regions of both hemispheres, in the posterior frontal, central, parietal regions of the right hemisphere and significantly higher values of the spectral power of theta oscillations in the right frontal, left parietal and central regions of both hemispheres. It was concluded that changes in spontaneous and induced electrical activity of the brain in patients with post-COVID syndrome reflect a decrease in the overall level of functional activity of the brain due to a violation of the regulatory influences of the limbic-reticular structures. In this case, a sufficient level of cortical activation is not provided, which is necessary for the optimal process of processing information and ensuring an adequate level of directed attention and short-term memory.

Keywords: post-COVID syndrome, neurophysiology, EEG

The coronavirus is spreading around the world at a rapid pace. Every day, a huge number of new cases are recorded in different parts of the globe. A global pandemic is causing panic and stress for many people, because this new virus has not yet been fully studied. The statistics will change as the number of patients grows. That the frequency of neurological complications in patients with a more severe course of the disease will increase [1, 2, 5]. These complications can be on a par with an altered mental status and, possibly, acute cerebrovascular disease, etc. Another danger that people with an unstable and vulnerable psyche are exposed to during the coronavirus pandemic is an increased level of stress and anxiety. The World Health Organization has already acknowledged that the pandemic is causing an increased level of anxiety in the population [2, 4].

Post-COVID syndrome is a consequence of the coronavirus infection COVID-19, in which up to 20% of people who have had a coronavirus infection suffer from long-term symptoms lasting up to 12 weeks or longer. There are several hypotheses that do not contradict each other [11, 14]. The SARS-CoV-2 virus directly damages the cells of the lungs, heart, blood vessels, brain, kidneys, stomach and intestines. The virus is neutrotropic, damaging cells in the brain and large nerves, causing a wide variety of symptoms, from sleep problems and anxiety disorders to cardiac and respiratory rhythm disturbances [13, 14].

The aim of the work was a psychophysiological research of the functional state of the brain and cognitive functions in patients with post-COVID syndrome.

Materials and research methods. The research included 76 patients (47 women and 29 men, middle age 33.24±3.11 years) with post-COVID syndrome. The control group consisted of 32 healthy subjects (24 women and 8 men, middle age 31.72±2.61 years). The duration of the disease at the time of the examination averaged 2.93±1.45 months.

The clinical view of the disease in patients was dominated by complaints of general weakness and fatigue (100%), decreased performance and a feeling of constant fatigue (100%), decreased concentration (87%), and memory impairment (58%). In addition, patients complained of increased anxiety (84%), a feeling of constant internal tension (65%), decreased mood background (72%), decreased appetite (60%), sleep disturbances (59%), headaches (55%), dizziness (51%), palpitations and pain in the left half of the chest, not associated with physical activity (49%), feeling short of breath (32%), lipothymic conditions (28%).

EEG registration was used as electrophysiological research methods. When registering EEG in a state of calm wakefulness with eyes closed. EEG recording was performed on 16 channels in leads Fp1, Fp2, F3, F4, F7, F8, T3, T4, T5, T6, C3, C4, P3, P4, O1, and O2 with monopolar mounting of electrodes with a combined ear reference. The electrodes were placed in accordance with the international system of 10-20%. After removal of muscle and oculomotor artifacts, ten 8-s EEG segments were analyzed. The compression spectral analysis (CSA) of the EEG was performed using the fast Fourier transform algorithm to calculate the absolute (μV2/Hz) spectral power density of the rhythm signal in the following frequency ranges: delta from 0.5 to 3 Hz; theta 4 to 7 Hz; alpha 8 to 13 Hz; beta 1 from 14 to 18 Hz; beta 2 from 19 to 32 Hz. The delta and beta 2 ranges were not analyzed further due to the impossibility of a sufficiently complete exclusion of artifacts. The EEG was recorded and processed using the licensed program “Brain Surfing” (Russia).

Research results. EEG in patients with post-COVID syndrome showed higher values of the absolute power density of theta oscillations in the anterior and central-parietal regions of both hemispheres, compared to the representatives of the control group, which were statistically significant ($p<0.05$), as well as in right frontal (Fp2, F4), central (C3, C4) and left parietal (P3) leads.

PS patients also had significantly lower values of the absolute power density of alpha oscillations in the occipital (O1, O2) areas of both hemispheres (p<0.01), as well as in the posterior frontal (F8), central (C4) and parietal (P4) areas of the right hemispheres (p<0.01–0.05), compared with healthy subjects. According to the values of the total absolute power density of the beta rhythm in both hemispheres, the patients were comparable with healthy subjects who made up the control group (Tables 1 and 2).

Table 1

Values of absolute power densities (µV2/Hz) of theta, alpha and beta rhythms in patients with post-COVID syndrome and healthy subjects in the right hemisphere (M±m)

EEG leads	Theta range		Alpha range		Beta range	
	Healthy	Sick	Healthy	Sick	Healthy	Sick
Fp2	7,22±0,51	11,06±2,24*	14,12±1,86	13,74±1,86	13,67±1,27	12,89±1,69
F4	7,34±0,63	12,14±1,47**	15,44±1,83	16,15±1,47	9,87±0,69	10,94±1,83
F8	8,26±0,78	9,83±1,58	16,36±1,28	13,12±1,64*	8,12±0,79	9,12±1,51
T4	8,02±0,37	9,12±1,68	16,75±1,34	14,12±1,74	8,53±0,74	9,42±1,34
T6	8,13±0,56	9,09±1,76	17,24±1,36	15,72±1,86	7,13±0,73	8,09±1,47
C4	9,11±0,84	12,37±1,16*	22,31±1,94	17,35±2,44**	8,36±0,61	9,91±2,25
P4	10,03±0,93	11,78±1,89	29,13±2,93	20,12±2,36**	8,32±0,65	9,84±2,34
O2	9,85±0,88	11,12±2,41	33,41±3,78	24,24±2,72**	7,14±0,73	8,66±1,25

Note: the significance of differences in the indicators of patients and healthy subjects: *- p<0.05. **-p<0.01

Table 2

Values of absolute power densities (µV2/Hz) of theta, alpha and beta rhythms in patients with PS and healthy subjects in the left hemisphere (M±m)

EEG leads	Theta range		Alpha range		Beta range	
	Healthy	Sick	Sick	Healthy	Sick	Healthy

Fp1	7,31±0,69	9,11±1,98	13,24±1,37	13,86±1,47	13,43±0,92	11,32±1,86
F3	8,63±0,87	10,56±1,98	14,12±1,53	15,23±1,86	11,12±1,14	9,87±1,93
F7	9,09±0,95	9,21±1,78	14,53±1,19	14,32±1,93	9,95±0,87	9,17±1,29
T3	9,16±0,65	9,45±1,57	14,87±0,97	13,36±1,79	10,23±0,75	9,47±0,94
T5	9,08±0,59	8,85±1,43	14,42±1,52	14,42±2,45	9,25±0,48	9,19±0,93
C3	9,32±0,74	12,89±1,15*	19,22±1,83	18,92±2,11	9,78±0,93	10,14±2,46
P3	9,98±0,85	14,43±1,38**	25,32±2,14	23,96±2,45	9,84±0,85	11,46±2,37
O1	9,83±0,74	11,11± 1,86	29,78±2,82	22,18±2,14**	8,31±0,87	9,74±1,29

Note: the significance of differences in the indicators of patients and healthy subjects: *-p<0.05. **-p<0.01

The results of numerous researches demonstrate the dependence of the occurrence of neurotic and autonomic disorders on the functional activity of the structures included in the limbic-reticular system [2]. The main structures involved in the generation of endogenous potential are considered to be the hippocampus, the medial temporal lobe, the frontal and parietal regions, as well as subcortical structures, primarily the nonspecific nuclei of the thalamus and the reticular formation of the brainstem [13] (that is, the structures underlying the formation of emotional- motivated behavior, cognitive functions and those involved in the pathogenesis of psychovegetative disorders). Thus, the change in amplitude parameters detected during the study can serve as an objective neurophysiological indicator of cognitive and emotional impairment due to functional disintegration of the limbic-reticular structures in patients with PS. The dysfunction of these structures is indicated by an increase in the power of the theta rhythm, which is more pronounced in the right hemisphere, which most likely reflects the presence of a negative emotional background due to a high level of anxiety and depression in patients with PS. Our data are consistent with the results of a research of patients with depression, where an increase in the activity of the right hemisphere was found, along with a high content of slow waves in the EEG, which are considered a sign of a decrease in the functional state of the brain [1]. Increased theta activity in the temporal regions of the right hemisphere was previously found in patients with panic disorders and was interpreted as a dysfunction of the hypothalamic-septohippocampal system [2]. Currently, there are no ambiguous interpretations of the functional significance of the theta rhythm in the literature. A number of studies have recorded an increase in the spectral power of the theta rhythm in some narrow frequency subranges, in particular, in the upper subrange, during the perception of emotionally significant information [6]. These data indicate that an increase in the power of the theta rhythm correlates with the functional activation of brain activity. At the same time, a correlation was shown between the severity of the background theta rhythm and an increase in thalamic metabolic activity, which indicates a connection between the theta rhythm and inhibitory processes. It has also been shown that the power of the theta rhythm increases in the state of relaxation [5], and the decrease in the power of the theta rhythm is considered as a partially specific activation reaction [9]. These data suggest that an increase in the spectral power of the theta rhythm may be a correlate of a decrease in the functional activity of the cortex. Thus, an increase in the spectral power of the theta rhythm is evaluated both as a correlate of activation and as an indicator of inhibition of the functional activity of the cortex. However, the cases of an increase in the power of the theta rhythm during activation described in the literature refer only to data obtained in narrow subranges, and an increase in the power of the full theta rhythm is considered an expression of inhibitory processes. Along with an increase in the power of the theta rhythm in patients, a decrease in the power of alpha activity was observed, more pronounced in the right hemisphere. A number of authors consider the hippocampus as a structure that has inhibitory effects on the thalamo-cortical system.

In general, the results obtained suggest that the dysfunction of the limbic-reticular structures of the brain, which underlies the formation of the psych vegetative syndrome, may be an important neurophysiological mechanism for reducing attention and memory, as well as impaired adaptation in patients with post-COVID syndrome.

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