Features of the parameters of EEG in persons whose immune status is susceptible or resistant to chronic stress

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In animal experiments and clinical observations, it was found out that the reactions of the immune system to stress are characterized by features of individuality due to the individual reactions of the main stress-realizing systems: sympatho-adrenomedulary and hypothalamic-pituitary-corticoadrenal [1,2,3,4,5,6]. The secondary, but essential role is also played by stress-induced changes in vagus tone, blood levels of sex and thyroid hormones as well as parathyrin and calcitonin [6,7,8,9,10,11,12].

In order to find out the role induced by chronic stress changes in immune parameters of the sympatho-vagal balance in the previous study, we [13,14] compared the individuals who were retrospectively divided into two groups, almost identical to the average value of LF/HF ratio and its dispersion, but with opposite deviations from the standards of the links of immunity. In stress-sensitive individuals the integral state of Phagocytosis as Z-scores was compiled: $-1.82 \pm 0.39$, of Cellular link: $-1.69 \pm 0.21$, of Humoral link: $+0.23 \pm 0.19$ versus $+0.76 \pm 0.43$; $+0.23 \pm 0.26$ and $+0.76 \pm 0.11$ in stress-resistant persons respectively.

The immune profiles constructed on Z-scores can be divided into three networks. The first set contains 7 parameters (IL-6, Entropy of Leukocytyogram (LCG), Killing Index vs E. coli and Staph. aureus, Microbial Count E. coli, IgG and M) that are not significantly different from persons who are stress-sensitive or stress-resistant. 18 parameters of the second set (total Leukocytes, Segmented and Stub Neutrophils, Phagocytose Index vs E. coli and Staph. aur., Microbial Count Staph. aur., Bactericidity vs E. coli and Staph. aur., T-active, T-helper, T-cytolytic, Natural Killers and B-Lymphocytes, IgA, CIC, Popovych’s Adaptation Index of LCG as well as Bifidobacterium and Lactobacillus feces) to a greater or lesser degree are higher in stress-resistant persons. The 8 parameters of the third set (total and O-Lymphocytes, Monocytes and Eosinophils, Popovych’s Strain Index of LCG, TNF-α, IL-1 as well as Hemolytica E. coli) are higher in stress-sensitive persons.

Previously, in our laboratory, significant relationships were found between the parameters of phagocytic, cellular and humoral links of immunity, on the one
hand, and HRV and EEG, on the other hand, as well as between changes in the immune and neural parameters caused by balneotherapy [15,16,17,18,19,20]. Hence, a hypothesis that, for the same states of the autonomic nervous system, the differences in immune responses to chronic stress were due to the features of the EEG. The verification of this hypothesis was the goal of this study.

**Material and methods.** The object of observation were 32 men (aged 24-70 years old) and 8 women (39-71 years old) with chronic pyelonephritis in remission. The criterion for inclusion was the magnitude of the sympatho-vagal balance index LF/HF which exceeded the age norm by 0,5 σ.

We recorded the electrocardiogram for 7 min in II group to assess the parameters of HRV [21,22] (software and hardware complex “CardioLab+HRV” produced by “KhAI-MEDICA”, Kharkiv, Ukraine). For the further analysis the following parameters of heart rate variability (HRV) were selected. Temporal parameters (Time Domain Methods): the standard deviation of all NN intervals (SDNN), the square root of the mean of the sum of squares of differences between adjacent NN intervals (RMSSD), the percent of interval differences of successive NN intervals greater than 50 ms (pNN50).

Spectral parameters (Frequency Domain Methods): spectral power density (SPD) bands of HRV: high-frequency (HF, range 0,4÷0,15 Hz), low-frequency (LF, range 0,15÷0,04 Hz), very low-frequency (VLF, range 0,04÷0,015 Hz) and ultra low-frequency (ULF, range 0,015÷0,003 Hz). Classical indexes were calculated: LF/HF, LFnu =100 %•LF/(LF+HF) and Baevskiy’s Activity Regulatory Systems Index (BARS1) as well as the Entropy (h) of normalized SPD using CE Shannon’s formula:

$$h_{HRV} = -[SPD_{HF} \cdot \log_2 SPD_{HF} + SPD_{LF} \cdot \log_2 SPD_{LF} + SPD_{VLF} \cdot \log_2 SPD_{VLF} + SPD_{ULF} \cdot \log_2 SPD_{ULF}] / \log_2 4.$$  

Then the EEG was recorded for 25 sec by means of the hardware-software complex “NeuroCom Standard” (produced by KhAI Medica, Kharkiv, Ukraine) monopolar in 16 loci (Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2) by 10-20 international system, with the reference electrodes A and Ref on tassels of the ears. The following options were considered – the average EEG amplitude (µV), modal frequency (Hz), frequency deviation (Hz), index (%), coefficient of asymmetry (%), absolute (µV²/Hz) and relative (%) SPD of basic rhythms: β (35÷13 Hz), α (13÷8 Hz), θ (8÷4 Hz) and δ (4÷0,5 Hz) in all loci, according to the instructions of the device. In addition, Laterality Index (LI) was calculated for SPD of each rhythm by using the formula:

$$LI, \% = \Sigma [200 \cdot (Right - Left)/(Right + Left)]/8.$$  

We calculated also the Entropy (h) of normalized SPD for each locus by using CE Shannon’s formula:

$$h = -(SPD_\alpha \cdot \log_2 SPD_\alpha + SPD_\beta \cdot \log_2 SPD_\beta + SPD_\theta \cdot \log_2 SPD_\theta + SPD_\delta \cdot \log_2 SPD_\delta) / \log_2 4.$$  

Normal values are borrowed from the instructions for devices as well as databases of the Truskavets’ Scientific School [15,16,17,18,19,20].

Results were processed by using the software package “Statistica 5.5”.

**Results and discussion.** First of all, it has been stated that stress-sensitive and stress-resistant individuals do not differ significantly in terms of HRV parameters, with the exception of entropy (Table 1).

For the purpose of a one-scale evaluation of various parameters of EEG, all of them were listed in the Z-score by the formula:

$$Z = (\text{Variable/Norm} - 1)/\text{Coefficient of Variation}.$$
After the EEG parameters screening, two profiles have been created that reflect the differences between the two clusters of individuals. The first profile (Fig. 1) contains the parameters that in stress-sensitive individuals are in the range of: –0,5σ ÷ +0,5σ, that is, in the zone of narrowed standards, whereas in stress-resistant individuals they are to some degree elevated, or at least exceed those who are stress-sensitive individuals.

In our interpretation, this means that the Amplitude of δ-rhythm and SPD of δ-rhythm in loci O1, F4, P4, F3, O2, T3, C3, T4, T5, P3, T6, Fp2 as well as Deviation of α-rhythm, which are higher than the average standards prevent the inhibition of phagocytosis and cellular immunity, which is accompanied by a sympathetic shift of the sympatho-vagal balance. Another factor of immune protection is the placement of the SPD of θ-rhythm in locus T3 in the upper zone of standard.

On the other hand, the factors listed above result in the enhancement of humoral immunity that is absent in persons susceptible to stress.

![Fig. 1. Profile of parameters of EEG, the level of which is higher in stress-resistant individuals](image)

The second profile (Fig. 2) contains EEG parameters, each of which in stress-resistant individuals is lower than in stress-sensitive individuals.

Visually you can select two network parameters. The first set has a significantly pronounced θ-rhythm Asymmetry, increased Entropy in locus T5 and
also SPD in locus F8 in stress-sensitive individuals, whereas in stress-resistant individuals, the Asymmetry is much less pronounced and the other two parameters are quite normal. Consequently, they can be interpreted as factors of suppression of phagocytosis and cellular immunity.

![Fig. 2. Profile of parameters of EEG, the level of which is lower in stress-resistant individuals](image-url)

The second set consists of parameters of β-rhythm as well as Entropy in locus F8, whose Z-scores fluctuates around zero in stress-sensitive individuals, whereas in stress-resistant individuals all of them are in the lower norm zone. Apparently, such a state of β-rhythm prevents the suppression of phagocytosis and cellular immunity, and also causes the activation of humoral immunity under conditions of chronic stress. Additional preventive factors are the left-side lateralization of α- and θ-rhythms (see Table 2).

The method of discriminant analysis forward stepwise [23] revealed 29 parameters (variables) that characterize the features of EEG profile of stress-sensitive and stress-resistant persons. Another 7 variables are not included in the model, but they are worth attention (Tables 2 and 3).

### Discriminant Function Analysis Summary for EEGs parameters of stress-sensitive and stress-resistant individuals

Step 29, N of variables in model: 29; Grouping: SS&SR. Wilks’ Λ: 0.034; approx. F\(_{(29)} = 9.8\); p = 0.0003

| Variables currently in the model | Norm (88) | Cv | SS (20) | SR (20) | Wilks’ Λ | Partial Λ | F remove | p-level | Tolerance |
|---------------------------------|-----------|----|---------|---------|-----------|-----------|----------|---------|-----------|
| F3-β SPD, %                     | 26.3±1.7  | 0.609 | 28.3±3.3 | 17.8±1.9 | .073      | .468      | 11.3     | .007    | .014      |
| F8 Entropy                      | 0.77±0.02 | 0.207 | 0.81±0.03 | 0.69±0.05 | .061      | .559      | 7.9      | .019    | .064      |
| P4-6 SPD, %                     | 19.1±1.3  | 0.661 | 19.2±2.7 | 34.9±5.5 | .043      | .799      | 2.5      | .144    | .033      |
| Fp2-6 SPD, %                    | 24.0±2.0  | 0.794 | 24.4±4.1 | 34.3±5.0 | .035      | .964      | 0.4      | .554    | .039      |
| F4-5 SPD, μV/Hz                 | 89±9      | 0.994 | 137±40  | 252±68  | .077      | .441      | 12.7     | .005    | .019      |
| T5-β SPD, μV/Hz                 | 107±11    | 0.982 | 91±20   | 56±6    | .110      | .310      | 22.3     | .001    | .069      |
| T4-5 SPD, %                     | 21.9±1.5  | 0.654 | 28.1±4.8 | 37.7±4.6 | .050      | .688      | 4.5      | .059    | .023      |
| T5 Entropy                      | 0.76±0.01 | 0.169 | 0.84±0.02 | 0.75±0.05 | .065      | .528      | 8.9      | .014    | .090      |
| T3-6 SPD, %                     | 20.2±1.4  | 0.635 | 29.7±4.6 | 39.8±5.9 | .157      | .217      | 36.0     | 10-4    | .014      |
| F9-5 SPD, %                     | 22.6±1.7  | 0.692 | 28.6±4.3 | 45.1±5.4 | .118      | .290      | 24.5     | .001    | .005      |
| T3-6 SPD, μV2/Hz                | 26.0±1.9  | 0.700 | 23.1±3.9 | 33.3±5.1 | .035      | .987      | 0.1      | .723    | .091      |
| T4-6 SPD, %                     | 31.3±1.9  | 0.584 | 34.8±4.3 | 26.9±2.6 | .061      | .559      | 7.9      | .018    | .026      |
| T5-5 SPD, %                     | 19.1±1.6  | 0.794 | 24.8±3.8 | 34.8±6.4 | .053      | .645      | 5.5      | .041    | .053      |
### Table 3

**Summary of Stepwise Analysis.** The scale of ranks for variables

| Variables currently in the model | F to enter | p-level | A         | F value | p-level |
|----------------------------------|------------|---------|-----------|---------|---------|
| F3-β SPD, %                      | 7,4        | .010    | .837      | 7,4     | .010    |
| F8 Entropy                       | 5,1        | .030    | .736      | 6,6     | .003    |
| P4-δ SPD, %                      | 3,1        | .088    | .678      | 5,7     | .003    |
| Fp2-δ SPD, %                     | 5,0        | .031    | .593      | 6,0     | .001    |
| F4-δ SPD, μV/Hz                   | 2,6        | .114    | .550      | 5,6     | .001    |
| T5-β SPD, μV/Hz                   | 1,8        | .192    | .522      | 5,0     | .001    |
| T4-δ SPD, %                      | 1,5        | .229    | .499      | 4,6     | .001    |
| T5 Entropy                       | 2,0        | .165    | .468      | 4,4     | .001    |
| T3-δ SPD, %                      | 1,9        | .174    | .440      | 4,2     | .001    |
| F3-δ SPD, %                      | 1,7        | .206    | .416      | 4,1     | .001    |
| T3-θ SPD, μV/Hz                   | 5,3        | .029    | .349      | 4,7     | <10⁻³   |
| T4-β SPD, %                      | 5,2        | .030    | .293      | 5,4     | <10⁻³   |
| T5-δ SPD, %                      | 2,5        | .125    | .267      | 5,5     | <10⁻³   |
| α Laterality Ind, %              | 2,7        | .110    | .240      | 5,6     | <10⁻⁴   |
| T3-β SPD, %                      | 2,1        | .159    | .221      | 5,6     | <10⁻⁴   |
| O2-δ SPD, %                      | 2,5        | .127    | .199      | 5,8     | <10⁻⁴   |
The information about the variables included in the model is condensed in the canonical discriminant root. The sum of products of raw coefficients of the value of discriminant variables together with the constant (Table 4) gives the values of roots for each person and allows their visualization (Fig. 3).

### Table 4

| Variables currently in the model | Stress-sensitive | Stress-resistant | Standardized | Structural | Raw |
|----------------------------------|------------------|------------------|--------------|------------|-----|
| F3-β SPD, %                     | +0.12 ± 0.21     | −0.53 ± 0.12     | −6.299       | 0.083      | −5.513 |
| T3-β SPD, %                     | +0.06 ± 0.26     | −0.65 ± 0.15     | 8.134        | 0.072      | 5.073  |
| T3-β SPD, μV²/Hz                | −0.12 ± 0.19     | −0.44 ± 0.06     | −3.666       | 0.047      | −0.643 |
| C4-β SPD, %                     | +0.10 ± 0.19     | −0.41 ± 0.13     | −2.682       | 0.065      | −2.303 |
| P3-β SPD, %                     | −0.11 ± 0.16     | −0.45 ± 0.12     | 1.293        | 0.052      | 1.194  |
| T5-β SPD, μV²/Hz                | −0.15 ± 0.19     | −0.48 ± 0.06     | 3.208        | 0.050      | 0.494  |
| F4-β SPD, %                     | +0.20 ± 0.24     | −0.32 ± 0.21     | 2.296        | 0.049      | 1.503  |
| T4-β SPD, %                     | +0.19 ± 0.24     | −0.24 ± 0.14     | 4.213        | 0.048      | 2.692  |
| F8 Entropy                      | +0.26 ± 0.22     | −0.48 ± 0.32     | 2.672        | 0.058      | 13.90  |
| T5 Entropy                      | +0.69 ± 0.19     | −0.06 ± 0.37     | 3.238        | 0.054      | 13.91  |
| F8-θ SPD, %                     | +0.44 ± 0.25     | −0.09 ± 0.18     | −4.122       | 0.052      | −9.972 |
| θ Asymmetry, %                  | +1.41 ± 0.41     | +0.64 ± 0.27     | 1.440        | 0.047      | 0.0706 |
| α Laterality Ind, %             | −1 ± 8           | −21 ± 5          | 2.404        | 0.063      | 0.0794 |
| P4-δ SPD, %                     | +0.01 ± 0.21     | +1.25 ± 0.44     | 2.492        | −0.076     | 1.287  |
| F3-θ SPD, %                     | +0.38 ± 0.28     | +1.44 ± 0.35     | −12.23       | −0.071     | −5.641 |
| O2-δ SPD, %                     | +0.45 ± 0.20     | +1.37 ± 0.44     | −4.914       | −0.057     | −2.454 |
| F4-δ SPD, %                     | +0.52 ± 0.37     | +1.55 ± 0.47     | 5.014        | −0.051     | 1.920  |
| δ Amplitude, μV                 | +0.21 ± 0.34     | +1.41 ± 0.63     | 12.71        | −0.050     | 0.9567 |
| Fp2-δ SPD, %                    | +0.02 ± 0.21     | +0.54 ± 0.26     | −0.977       | −0.046     | −0.0483 |
| P3-δ SPD, μV²/Hz                | +0.09 ± 0.26     | +0.90 ± 0.46     | −2.649       | −0.046     | −0.205 |
| T6-δ SPD, %                     | +0.28 ± 0.23     | +0.86 ± 0.32     | 3.968        | −0.045     | 0.214  |
| C3-δ SPD, %                     | +0.50 ± 0.32     | +1.26 ± 0.38     | −0.291       | −0.045     | −0.1847 |
| T4-δ SPD, %                     | +0.43 ± 0.33     | +1.11 ± 0.32     | −3.774       | −0.044     | −1.830 |
As it can be seen, stress-susceptible and stress-resistant persons are very clearly delineated. Significantly lower individual values of the discriminant root in the stress-resistant persons as compared to those in the stress-susceptible ones, reflect, on the one hand, lowering or localization of the parameter values of β-rhythm and θ-rhythm and Entropy in loci F8 and T5 in the low zone of the standards as well as the left-side lateralization of α-rhythm which correlates with the root positively, whereas in the stress-susceptible individuals, the Z-scores of these parameters fluctuate around zero or elevated a bit and α-rhythm is symmetric.

On the other hand, such a disposition reflects the significantly increased values of δ-rhythm parameters in the stress-resistant persons and the magnitude of θ-rhythm and α-rhythm parameters is located in the upper zone of the standards, which correlate with the root negatively, whereas in the stress-susceptible individuals, the Z-scores of these parameters fluctuate around zero or moderately elevated.

Another aspect is related to the sexual dimorphism in the response of EEGs parameters to some chronic stress. In each set women are identified with different colors. As you can see, both sexes are mixed in a stress-resistant set. In the stress-sensitive set, there was only one woman, but her root is not different from the roots of men. Consequently, sex does not determine the nature of the EEGs response to chronic stress.

Following our algorithm, we have given Coefficients and Constants for Classification Functions (Table 5) for the retrospective identification of stress-susceptible and stress-resistant persons.
## Table 5

| Variables currently in the model | Stress-sensitive | Stress-resistant |
|---------------------------------|------------------|------------------|
| F3-β SPD, %                     | -15.81           | -10.29           |
| F8 Entropy                      | 531.9            | 387.7            |
| P4-8 SPD, %                     | 3.676            | 2.340            |
| Fp2-8 SPD, %                    | -.492            | .009             |
| F4-8 SPD, µV²/Hz                | -.693            | -.465            |
| T5-β SPD, µV²/Hz                | 1.285            | .772             |
| T4-8 SPD, %                     | -5.673           | -3.774           |
| T5 Entropy                      | 541.6            | 397.2            |
| T3-8 SPD, %                     | 8.862            | 5.512            |
| F3-5 SPD, %                     | -17.81           | -11.96           |
| T3-θ SPD, µV²/Hz                | .558             | .360             |
| T4-β SPD, %                     | 8.451            | 5.657            |
| T5-8 SPD, %                     | 3.562            | 2.390            |
| α Laterality Index, %           | 2.207            | 1.383            |
| T3-β SPD, %                     | 12.89            | 7.625            |
| O2-8 SPD, %                     | -6.624           | -4.076           |
| F4-8 SPD, %                     | 7.245            | 5.252            |
| F4-β SPD, %                     | 7.855            | 6.296            |
| F8-8 SPD, %                     | -32.40           | -22.05           |
| T3-β SPD, µV²/Hz                | -1.686           | -1.019           |
| Deviation α, Hz                 | -92.03           | -57.53           |
| T6-8 SPD, %                     | 5.940            | 3.718            |
| C3-8 SPD, %                     | -1.066           | -.913            |
| δ Amplitude, µV                 | 30.91            | 20.98            |
| O1-8 SPD, µV²/Hz                | -.571            | -.383            |
| P3-8 SPD, µV²/Hz                | -.569            | -.356            |
| C4-β SPD, %                     | -8.841           | -6.451           |
| θ Asymmetry, %                  | 1.980            | 1.248            |
| P3-β SPD, %                     | 5.521            | 4.282            |
| Constants                       | -567.2           | -310.4           |

The received data along with previously published [24,25,26,27,28,29] seems to make a modest contribution to the development and specification of the concept of individual reactivity of the body [1].

Another aspect is related to the concept of ‘immunological homunculus’ put forward by KJ Tracey in 2007 [30].

According to the author, there is a structured, somatotopically organized neural network that controls the specific components of the immune response through the connection of the input and output. Such a theoretical organization is similar to the classic homunculus which demonstrates that specific areas of the brain control the specific parts of the body and in the future it will be possible to construct an “immunological homunculus”. For example, one region of the brain can control cytokine responses in the liver and the other - the ac-
tivation of T cells in the spleen or lymph nodes. Certain centers can integrate the information about the presentation of antigens while others are about the process of maturation of dendritic cells. Separate neurological domains in the central nervous system may regulate the state of general readiness of the innate immunity to respond to pathogens or injuries. The existence of neuro-anatomical maps of cholinergic anti-inflammatory reflex is a significant step towards the identification of other domains in the immunological homunculus which is crucial for maximizing the body protection and maintaining health during immune responses.

![Fig. 4. KJ Tracey's scheme of immunological homunculus [30]](image)

However, in subsequent works of this laboratory [31,32], this hypothesis was not developed properly. And only in 2018, it was mentioned in the review [33] but, unfortunately, without any specification.

Our attention was driven to the fact that the author’s scheme (Fig. 4) at the end of each signature is a question mark, that is, it is not a statement, but a hypothesis. Under the influence of this hypothesis we carried out the research for its verification [15,16,17,18,19,20].

If you reformat the parameters of the EEG of stress-susceptible and stress-resistant individuals within the framework of the KJ Tracey’s scheme of immunological homunculus [30], then they will organically fit into it (Table 6).

Assuming KJ Tracey, we can state the following: firstly, the nerve structures, responsible for one or another immune response are located in both hemispheres, but their activity is uneven.

Secondly, in the same locus there are different neurons, some of which generate immuno-protective δ-rhythm, while other generates immuno-suppressive β-rhythm. Thirdly, the activity of the nervous structures is significantly different in persons whose immune status is different in response to chronic stress, but rather to stress-induced sympathetic displacement of the sympathetic-vagal balance.

In particular, the activity of the nerve structures that activate the release of the cytokines, but is symmetrical in the structures responsible for the clonal expansion and regulation of T cells.
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| Immune response and EEG Z-score | Stress-sensitive | Stress-resistant |
|---------------------------------|------------------|------------------|
| **KJ Tracey’s hypothesis**      |                  |                  |
| **Immune compartment cytokine release** |                  |                  |
| F4-δ SPD, μV/Hz                 | +0.53±0.46       | +1.83±0.77       |
| F4-β SPD, %                     | +0.52±0.37       | +1.55±0.47       |
| F3-δ SPD, %                     | +0.20±0.24       | −0.32±0.21       |
| F3-β SPD, %                     | +0.38±0.28       | +1.44±0.35       |
| **Clonal expansion**            |                  |                  |
| P4-δ SPD, %                     | +0.01±0.21       | +1.25±0.44       |
| P4-β SPD, %                     | +0.05±0.19       | −0.46±0.13       |
| P3-δ SPD, μV/Hz                 | +0.09±0.26       | +0.90±0.46       |
| P3-β SPD, %                     | −0.11±0.16       | −0.45±0.12       |
| **Dendritic cells maturation**  |                  |                  |
| T3-δ SPD, %                     | +0.74±0.36       | +1.53±0.46       |
| T3-θ SPD, μV/Hz                 | −0.16±0.22       | +0.40±0.28       |
| T3-β SPD, %                     | +0.06±0.26       | −0.65±0.15       |
| T3-β SPD, μV/Hz                 | −0.12±0.19       | −0.44±0.06       |
| T4-δ SPD, %                     | +0.43±0.33       | +1.11±0.32       |
| T4-β SPD, %                     | +0.19±0.24       | −0.24±0.14       |
| **T cells regulation**          |                  |                  |
| T5-δ SPD, %                     | +0.38±0.25       | +1.04±0.42       |
| T5-β SPD, %                     | −0.11±0.17       | −0.57±0.15       |
| T5-β SPD, μV/Hz                 | −0.15±0.19       | −0.48±0.06       |
| T5 Entropy                      | +0.69±0.19       | −0.06±0.37       |
| T6-δ SPD, %                     | +0.28±0.23       | +0.86±0.32       |
| T6-β SPD, μV/Hz                 | +0.38±0.44       | −0.51±0.09       |
| **Activation of memory B cells**|                  |                  |
| Fp2-δ SPD, %                    | +0.02±0.21       | +0.54±0.26       |
| **Our hypothesis**              |                  |                  |
| **Activation of Phagocytosis?**  |                  |                  |
| O1-δ SPD, μV/Hz                 | +0.06±0.25       | +1.61±1.16       |
| O2-δ SPD, %                     | +0.45±0.20       | +1.37±0.44       |
In addition, we want to supplement the concept with our own hypothesis about the existence in O1 and O2 loci of the nerve structures generating δ-rhythm that activate phagocytosis, or more precisely, prevent its depression caused by stress.

**Conclusion.** We have managed to prove that for the same states of the autonomous nervous system, the differences in immune responses to chronic stress due to the features of the EEGs parameters are markers of the individual reactivity.

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**ACCORDANCE TO ETHICS STANDARDS**

Tests in patients are conducted in accordance with positions of Helsinki Declaration 1975, revised and complemented in 2002, and directive of National Committee on ethics of scientific researches. During realization of tests from all participants the informed consent is got and used all measures for providing of anonymity of participants.

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RESEARCH ARTICLE

Features of the Parameters of EEG in Persons Whose Immune Status is Susceptible or Resistant to Chronic Stress

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Introduction. In experiments on animals and clinical observations, it was found out that the reactions of the immune system to stress are characterized by features of individuality due to the individual reactions of the main stress-realizing systems: sympa-tho-adrenomedul
and hypothalamic-pituitary-corticoadrenal. The secondary, but essential role is also played by stress-induced changes in vagus tone, blood levels of sex and thyroid hormones as well as parathyrin and calcitonin. In order to find out the role induced by chronic stress changes in immune parameters of the sympatho-vagal balance in the previous study, we compared the individuals who were retrospectively divided into two groups, almost identical to the average value of LF/HF ratio and its dispersion, but with opposite deviations from the standards of the links of immunity. Previously, in our laboratory, significant relationships were found out between the parameters of phagocytic, cellular and humoral links of immunity, on the one hand, and HRV and EEG, on the other hand. Hence, a hypothesis that, for the same states of the autonomic nervous system, the differences in immune responses to chronic stress were due to the features of the EEG. The verification of this hypothesis was the purpose of this study.

**Materials and methods.** The object of the observation were 32 men (aged 24-70 years old) and 8 women (39-71 years old) with chronic pyelonephritis in remission. The criterion for inclusion was the magnitude of the sympatho-vagal balance index LF/HF, which exceeded the age norm by 0.5 σ. The parameters of HRV ("CardioLab+HRV", "KhAI-MEDICA") were recorded as well as EEG ("NeuroCom Standard", KhAI MEDICA) monopolar in 16 loci by 10-20 international system. Results were processed by using the software package ‘Statistica 5.5’.

**Results.** After the EEG parameters screening, two profiles have been created that reflect the differences between the two groups of individuals. The first profile contains the parameters that in stress-sensitive individuals are in the zone of narrowed standard, whereas in stress-resistant individuals they are to some degree elevated, or at least exceeded those in stress-sensitive individuals. This means that the Amplitude of δ-rhythm and SPD of δ-rhythm in loci O1, F4, P4, F3, O2, T3, C3, T4, T5, P3, T6, Fp2 as well as Deviation of α-rhythm, which are higher than the average standard prevents the inhibition of phagocytosis and cellular immunity, which is accompanied by a sympathetic shift of sympatho-vagal balance. On the other hand, the factors listed above, result in the enhancement of humoral immunity that is absent in persons susceptible to stress.

The second profile contains EEG parameters, each of which in stress-resistant individuals is lower than that of stress-sensitive individuals. The first set has a significantly pronounced θ-rhythm Asymmetry, increased Entropy in locus T5 and also SPD in locus F8 in stress-sensitive individuals, whereas in stress-resistant individuals the Asymmetry is much less pronounced and the other two parameters are quite normal. The second set consists of parameters of β-rhythm as well as Entropy in locus F8, whose Z-scores fluctuates around zero in stress-sensitive individuals, whereas in stress-resistant individuals all of them are in the lower standard zone. Apparently, such a state of β-rhythm prevents the suppression of phagocytosis and cellular immunity and also causes the activation of humoral immunity under conditions of chronic stress. Additional preventive factors are the left-side lateralization of α- and θ-rhythms.

**Conclusions.** We have proved that for the same states of the autonomic nervous system, the differences in immune responses to chronic stress due to the features of the EEGs parameters are markers of the individual reactivity.

**Key words:** chronic stress, sympatho-vagal balance, immunity, EEG, individual reactivity.