THE BODY VEGETATIVE BALANCE STUDY BY TESTING SKIN SYMPATHETIC REACTIONS

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The aim of the investigation was to identify the regularities of skin sympathetic reaction changes in healthy people and patients with pathology of basal systems of organs.

Materials and Methods. We examined 120 patients with various pathologies, and 30 healthy people. The patients were chosen by random sampling technique, and divided into 12 clinical experimental groups. Each group (5 male and 5 female) consisted of the patients with severe and moderate pathology of a particular visceral system with significant dysfunctions or structural damage of organ tissues.

Results. The study demonstrated healthy people to have segmental skin sympathetic reactions balanced in their intensity compared to the patients with particular body system pathology, who were found to have the typical for this pathology changes in the activity of skin sympathetic reactions in distal extremities. In the course of the investigation we revealed 12 pairs of skin segments responsible for vegetative supply, the findings making a considerable contribution to the study of segmental nerve supply of the body.

Key words: skin sympathetic reactions; autonomic nervous system; skin segments of vegetative provision; dynamic segmental diagnostics.

The clinical manifestations of diseases are caused substantially by the regulatory effects of the sympathetic part on the adaptive-trophic processes in organs and tissues [1]. The abnormality of such processes leads to the functional pathology of the visceral systems of the body and in some cases – to the organic damage of the organ tissues as the result of tissue hypoxia against the background of sympathoadrenal effects on the microcirculation system. In this connection, the study of the state of the autonomic nervous system (ANS), in particular its sympathetic link can significantly improve the efficiency of treatment of diseases.

One of the techniques to investigate the sympathetic part of ANS is the study of electrodermal activity (EDA) known from XIX century mainly by the scientific papers of I.R. Tarkhanov, a Russian physiologist (the research of skin electric potentials) and Ch. Fere, a French neurologist (the study of electrocutaneous resistance) [2, 3]. Traditionally, the basis of Fere method was designated by the galvanic skin reaction (GSR) [4]. Moreover, during the process of GSR studying, the intended change of the activity of segmental part of the sympathetic nervous system is considered to be impossible, due to which low power testing current (the voltage of 2–4 V and the current intensity of 10-40 μA) is used that does not have the property to change considerably the sympathetic skin activity at the place where the electrodes are installed [5]. In addition, it is considered inadmissible to use the skin areas with insufficient sympathetic provision which makes it necessary to use the most informative variants of the signal diversion during the process of GSR studying [4].

The most researchers consider three mechanisms affecting the electrocutaneous resistance (ECR) and EDA to be the basic ones [4, 6–7]: perspiration mechanism (pulse intensification in the nerve endings of the upper skin layers results in the increase of the sweat production in the perspiratory glands and the reduction of ECR), ionic mechanism (the parameters of the skin electrolytes and the processes occurring on the membranes of the cells of upper skin layers have an effect on values of ECR) and diffusion mechanism (the intensification of liquid transport through the skin in case of an increased vascular tone of the skin blood vessels results in ECR reduction).

The study of EDA on separate skin areas depends on the local sympathetic effects in the skin. To minimize the effect of the total sympathetic activity as a rule caused by psychogalvanic reflex (the definition of O. Veragutu, 1909) the patients should be in the state of the relaxed wakefulness in the course of the research. To initiate the local skin sympathetic reactions for the subsequent evaluation of their intensity a rather powerful testing signal is used in the form of electric current with the voltage of up to 21 V and the current intensity of 150–250 μA [8].

The research of segment skin sympathetic reactions has two aspects: scientific and practical. The scientific aspect consists in determining the systematic (morphological and functional) and intersystem (neurosomatic/neurovegetative) organization of the functions of vegetative provision. The practical value relates to the development of the technique to assess the vegetative balance of the body.

The aim of the investigation was to identify the regularities of skin sympathetic reaction changes in healthy people and patients with pathology of basal systems of the body.

The research objectives were to study the segmental skin sympathetic reactions in distal parts of the extremities in healthy people and in patients with severe and moderately severe forms of pathology of cardiovascular, bronchopulmonary, urogenital and digestive systems.

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Materials and Methods. We studied the results of dynamic segment diagnostics ("The method of dynamic segmental diagnostics", 2004). Permit for use a new medical technology No. ФС 2011/336. — Federal service of supervision in the sphere of public health and social development of the Russian Federation) in 120 patients (60 female and 60 male) aged from 14 to 67 years with the pathology of basal systems of organs. The control group consisted of 30 completely healthy people including 15 men and 15 women at the age of 18–25 years. The patients were chosen by random sampling technique, and divided into 12 clinical experimental groups. Each group (5 male and 5 female) consisted of the patients with severe and moderately severe pathology of a particular visceral system with significant dysfunctions or structural damage of organ tissues. The selection of patients and their division into groups gave an opportunity to reveal the peculiarities of the vegetative imbalance with specific changes of the intensity of the skin sympathetic reactions in the distal parts of the extremities in case of the pathologies of particular systems of the body. The diagnosis was made on the basis of the past history data, the patients` complaints and the results of clinical laboratory and instrumental investigations. Group 1 — the patients aged from 42 to 65 years with transmural myocardial infarction; group 2 — the patients aged from 14 to 46 years with essential arterial hypotension; group 3 — the patients aged from 51 to 67 years with malignant pulmonary neoplasms; group 4 — the patients aged from 27 to 53 years with acute diffuse glomerulonephritis; group 5 — the patients aged from 23 to 41 years with exacerbation of chronic cystitis and urolithiasis; group 6 — the patients aged from 36 to 55 years with acute pancreatitis; group 7 — the patients aged from 49 to 58 years with gatroptosis; group 8 — the patients aged from 21 to 39 years with active duodenal ulcer; group 9 — the patients aged from 27 to 46 years with irritable bowel syndrome; group 10 — the patients aged from 55 to 67 years with hepatic cirrhosis; group 11 — the patients aged from 15 to 43 years with exacerbation of chronic calculous cholecystitis; group 12 consisted of 10 women aged from 21 to 35 years with growing ovarian cysts (among them 5 — with corpus luteum cyst, and 5 — with a follicular cyst).

Each patient underwent 3 tests with 1–3-day interval using the devices POST-12.2 (Russia) and ARM Peresvet (Russia).

The skin sympathetic reactions were studied using the method of dynamic segmental diagnostics (DSD testing) based on EDA evaluation against the background of the stimulation of the nerve receptors in the testing zone using electrical current [9]. The testing current was direct, the voltage — 6–21 V; the current intensity was 150–250 μA. The active electrode (of negative polarity) was placed on distal parts of the extremities along the following conventional lines: 1) the palm surface of hands — along the palm-medial (HPMIL), the palm-median (HPMnL), palm-lateral (HPLL) lines; the dorsal part of hands — along the dorsal medial (HDMIL), dorsal median (HDMnL), dorsal lateral (HDLL) lines; 2) the dorsal part of the feet — along dorsal medial (FDMIL), dorsal median (FDMnL), dorsal lateral (FDLL) lines; and additional lines on the feet — along the medial (FML), lateral (FLL) and posterior (FPL) lines.

Normally the skin sympathetic reaction has three stages [9]: 1) increased EDA; 2) EDA stabilization, or the "plateau" stage; 3) skin EDA reduction. The first stage is characterized by ECR reduction within 5–60 s in the testing zone responding to the effect of the testing current on skin receptors. In addition, the device stabilizing the voltage records the current increase between the electrodes. The beginning of the second stage is indicated by the stabilization of the current intensity at its maximum values. The duration of the second stage is approximately 1–2 min. During the third stage ECR begins to increase and the device records the decrease of the current intensity; and in the course of about 5-10 min it decreases up to the initial values typical for the beginning of the test.

In practice, to save time, the dynamic segmental diagnostics, as a rule, is performed before the EDA stabilization stage, i.e. before the moment when the device starts recording stably high maximum values of the current intensity.

The test results of the skin sympathetic reactions were evaluated by the analysis of the vegetative activity provision (VAP) index corresponding to the current intensity on the "plateau" stage [8].

The data were statistically processed using software package Statistica 6.1. To evaluate the selective differences Wilcoxon–Mann–Whitney U-test for independent data was used. The differences were considered statistically significant if $p \leqslant 0.05$.

Results and Discussion. The findings of the dynamic segmental diagnostics of healthy people revealed that in distal parts of the extremities the intensity of skin sympathetic reactions is balanced, the calculated parameters of VAP of skin sympathetic reactions for different zones varied mainly within the range of 65–90 μA. During the similar study of the same group of healthy people in the state of neuropsychic excitement, VAP indices on the same skin areas increased not less than by 20 μA (Fig. 1). The reliability of the differences of the selected mean

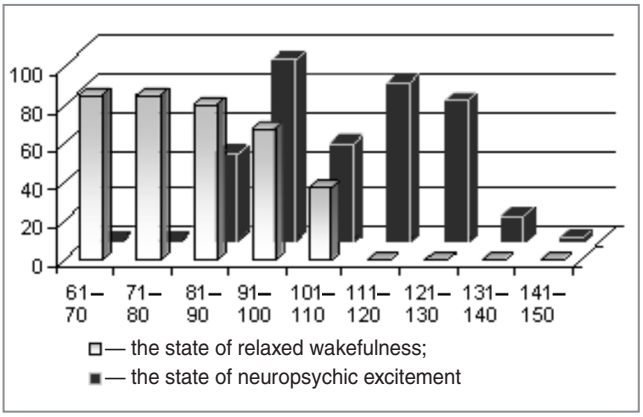

Fig 1. The change of the index of vegetative activity provision of skin sympathetic reactions in the group of healthy people (n=30) in the state of relaxed wakefulness and neuropsychic excitement. X-direction — values of indices of vegetative activity provision of skin sympathetic reactions, μA; Y-direction — frequency of VAP index, cases

Table 1

Comparison of indices of vegetative activity provision of skin sympathetic reactions on tested skin segments in the group of healthy people in the state of relaxed wakefulness and neuropsychic excitement (M±s)

Conventional lines	VAP indices on skin along the conventional lines, μA		t_{fact}*
	in the state of relaxed wakefulness (n=30)	in the state of neuropsychic excitement (n=30)	
HPMIL	73.50±3.96	97.50±3.87	39.9
HPMnL	88.40±3.11	116.90±5.66	25.0
HPLL	95.90±4.01	119.50±6.12	27.0
HDMIL	89.90±4.59	115.90±7.85	24.5
HDMnL	101.60±3.91	126.30±5.98	26.0
HDLL	101.40±3.31	124.60±5.37	35.4
FDMIL	65.50±2.60	90.20±4.43	32.9
FDMnL	69.70±1.75	94.00±4.49	38.6
FDLL	66.20±2.50	92.13±4.63	35.0
FML	82.70±3.22	111.20±82.37	19.8
FLL	76.70±2.78	102.10±6.11	23.0
FPL	82.40±3.40	108.80±7.92	24.9
Mean values in all lines	82.30±3.59	108.30±1.34	41.2

Note. The data are presented as M±s, where M — is the average arithmetic value; s — the mean-square deviation. * — the differences of sample mean values VAP in skin areas of the indicated lines in different conditions of testing are statistically significant if $p \leqslant 0.01$.

values at rest and excitement was evaluated using Student t-test for the associated data. The selected values of VAP indices of the skin sympathetic reactions significantly differed statistically in patients in the state of the relaxed wakefulness and neuropsychic excitement in all the tested skin areas (Table 1).

The findings proved the effect of the sympathetic nerve system on EDA (Fere–Tarkhanov phenomenon) [2, 3]. But the primary purpose of our research was the comparative evaluation of the activity of the skin sympathetic reactions on different skin areas of the distal parts of the extremities in health and disease (Fig. 2). The previous DSD testing of the patients with spinal injuries and a complete break of the spinal cord [10] showed the intensity of the skin sympathetic reactions above and below the injury to have no significant differences. We concluded the predominantly humoral nature of the psychogalvanic reflex intensity regulation.

To analyze the characteristics of VAP indices of the skin sympathetic reactions for each clinical experimental group, a separate comparison group was formed including 30 subjects selected by random sampling technique with any pathology type except the pathology typical for the analized group (Table 2). Taking into consideration a small size of the clinical experimental groups and the fact that the sampling variances of these groups differed by several times from those of the comparison groups, the differences were evaluated using Mann–Whitney test. For all the variants of comparison the differences appeared to be statistically significant if $p \leqslant 0.001$.

The patients of all clinical experimental groups had the imbalance of skin sympathetic reactions by their intensity in comparison with different VAP indices in different skin areas of distal parts of the extremities. Moreover, a specific fact was revealed: there was a statistically significant reduction or increase of VAP indices in patients of each clinical experimental group compared to a similar index in a corresponding comparison group in a typical for this somatic pathology area (segment).

For example, the most changes of VAP indices of skin sympathetic reactions for patients with transmural myocardial infarction (the first clinical experimental group) were recorded on the palm surface of a little finger and on the skin projection of the tendon of the ulnar wrist flexor, the mean value of VAP index for these patients was 11.0±2.62 μA, and in the corresponding comparison group it was 64.10±19.83 μA with a high statistically significant difference of these indices ($p<0.001$). Similar comparisons of VAP indices on a skin area typical for a peculiar type of pathology were made for all the clinical experimental groups (see Table 2), where the group number corresponds to the number of the skin area with typical (maximum) changes of VAP index specific to this group).

In patients with essential arterial hypotension (group 2) such typical changes of VAP index were recorded on the palm surface of a middle finger and on the skin projection of the tendon of the long palmar muscle. In group 3 (the patients with malignant pulmonary neoplasms) — on the palm surface of a thumb and on the skin projection of the tendon of the brachioradial muscle. In group 4 (the patients with acute diffuse glomerulonephritis) — on the medial surface of calcaneal bone from its lower edge towards the posterior edge of the medial ankle. In group 5 (the patients with exacerbation of chronic cystitis and urolithiasis) — on the skin of the lateral edge of the foot from a small toe in the direction of the posterior edge of the lateral ankle. In group 6 (the patients with acute pancreatitis) — on the skin of the medial edge of the foot from the big toe in the direction of the center of the medial ankle. In group 7 (the patients with gastroptosis) — on the dorsal foot surface in the direction from the second interdigital interspace to the projection of the tendon of the extensor digitorum longus. In group 8 (the patients with exacerbation of duodenal ulcer) — on the skin of the medial edge of a little finger and on the skin projection of the tendon of the ulnar extensor muscle of wrist. In group 9 (the patients with irritable bowel syndrome) — on the dorsal surface of a forefinger and on the skin projection of the tendon of the long abductor muscle of thumb. In group 10 (the patients with liver cirrhosis) — on the dorsal foot surface in the direction from the first interdigital interspace to the anterior margin of the medial ankle. In group 11 (the patients with the gallbladder pathology) — on the dorsal foot surface in the direction from the fourth interdigital interspace to the anterior margin of the lateral ankle. In group 12 (the patients with growing ovarian cyst) — on the skin of the dorsal surface of the III–IV fingers and on the skin projection of the little finger extensor tendon.

Thus, the performed research enabled to find the skin areas in distal parts of the extremities where the intensity

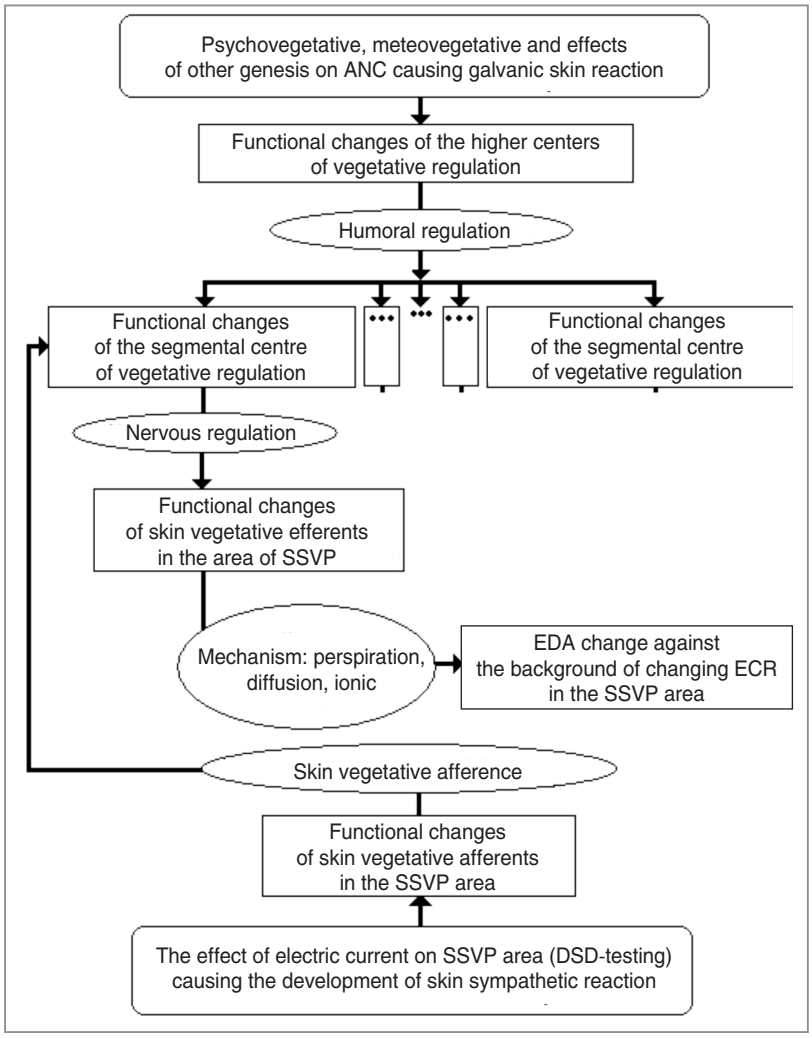

Fig. 2. The scheme of the development of galvanic skin and skin sympathetic reactions. SSVP — skin segment of vegetative provision

Table 2

Statistical characteristic of indices of vegetative provision of skin sympathetic reactions in clinical experimental groups and comparison groups

Group	Sample mean values in the groups (M±s)	
	Analysis group (n=10)	Comparison group (n=30)
1	11.00±2.62	64.10±19.83
2	12.10±3.11	65.40±21.04
3	10.00±2.11	69.80±17.23
4	138.50±4.70	66.90±20.65
5	124.50±4.86	57.50±19.95
6	132.90±5.78	64.90±18.49
7	11.40±2.84	78.90±18.48
8	134.50±6.92	58.10±22.18
9	134.90±3.18	63.70±22.42
10	11.30±2.87	65.10±23.45
11	136.20±5.87	61.60±16.89
12	157.70±5.08	62.90±23.93

of the skin sympathetic reactions is reliably low or high depending on the pathology type of the peculiar systems and organs in comparison with the patients with other pathologies (totally 12 symmetrical "skin segments of vegetative provision").

The examination of healthy people showed that homeostasis in the body is characterized by the balance of the VAP indices of skin sympathetic reactions on the skin segments of vegetative provision. The unbalanced indices indicate the imbalance in the vegetative provision of the internal systems of the body. In addition, the increase or decrease of the index of the vegetative activity provision of the skin sympathetic reaction on any skin segment in the distal parts of the extremities shows the failure of the vegetative provision of the corresponding visceral system that can be an "electrodermal marker" of the pathology of this system. Such failures of EDA can be recorded at any stage of the visceral systems diseases including the preclinical stage that gives an additional instrument to the doctor to diagnose the hidden or compensated forms of pathology.

Moreover, the detection of the skin segments of the vegetative provision is certain to indicate the segmental interaction between the effector vegetative neurons performing the vegetative provision of visceral systems of the body and cutaneous covering. Some authors show cerebrospinal innervation of internal organs preserves a metameric nature [11–13]. On the other hand, in

comparison with somatic segmental skin innervation having rather precise borders of dermatomes, the borders of segmental sympathetic provision of the skin surface are wider and blurred [14], since the metamer distribution of the vegetative nerve structures is masked by the overlap zones, so the segmental appurtenance of the organs and tissues in a healthy adult body is generally hidden [12]. However, in the papers of some authors there are indications of the more distinct evidence of the segmental innervation in the distal direction exactly (in the area of the fingers) [15–17].

Conclusion. The dynamic segmental diagnostics represents a new generation in the technologies of the vegetative nervous system research based on the testing of the skin sympathetic reactions against the background of the low level electric stimulation of the nerve receptors of the skin segments at the place of applying an active electrode. This medical technology solves the fundamental problem of revealing systemic (morphological and functional) and intersystem (neurosomatic/neurovegetative) organization of the vegetative provision. The dynamic segmental diagnostics enables to determine the functional state of the basic internal systems of the body and spinal nerves, the damage of vegetative fibers of peripheral nerves, as well as make a conclusion about the character of the vegetotrophic provision of any skin areas. The eventual manifestation of the segmental nature of vegetative provision is possible only against the background of pathological processes affecting the organs and systems of the body, and the finding of 12 pairs of skin segments of the vegetative provision in distal parts of the extremities is an essential contribution to the study of the segmental innervation of the organism.

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