DIAGNOSTIC AND TREATMENT METHODS

O.G. Argunova, A.A. Tappakhov, N.G. Dmitrieva,
A.N. Makarova, M.G. Ivanova

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STABILOMETRY IN THE COMPLEX REHABILITATION OF PATIENTS AFTER CEREBRAL STROKE

Postural disturbance are detected in about 80% of people after a stroke and significantly limit the patient's household and social activity, increase the risk of falls. Stabilometry is a highly informative method for studying the equilibrium function based on the analysis of the parameters of the center of pressure. The purpose of the study: clinical and stabilometric analysis of postural disorders in the complex rehabilitation of patients after a stroke. Materials and methods. The study involved 60 patients (40 men and 20 women, median age 61.0 [56.25; 65.75] years, median rehabilitation start time 30.0 [25.0; 40.75] days). All patients were divided into 2 groups: the first group consisted of 30 people with hemiataxy; the second group - 30 people with hemiparesis. All patients underwent complex rehabilitation and stabilotraining sessions. The dynamics of stabilometric parameters and clinical scales (NIHSS, Rivermead index, Rankin scale, Barthel scale) were assessed. Results. Both groups received statistically significant improvements in the area of the statokinesiogram, velocity of the center of pressure, energy index in both phases of the study, as well as in all clinical scales ($p < 0.001$). We did not reveal differences in the degree of changes in stabilometric parameters in patients with different stroke syndromes (hemiataxia or hemiparesis) before and after complex rehabilitation ($p > 0.05$). No correlation was found between stabilometric parameters and clinical scales. Conclusion. Stabilometry is a highly informative method for studying the balance function in patients after a stroke in complex rehabilitation, however, one should take into account the lack of correlation of its parameters with clinical scales.

Keywords: stroke, rehabilitation, stabilometry, stabilotraining, postural disorders, biofeedback.

Introduction. Stroke remains an urgent medical and social problem of modern society in the world and in Russia. According to the study of the global burden of stroke, from 1990 to 2010 there was an absolute increase in the number of patients with ischemic and hemorrhagic stroke in the world (by 37% and 47%, respectively). However, in high-income countries, the incidence and mortality from stroke have decreased significantly (ischemic - by 13% and 37%, hemorrhagic - by 19% and 38%, respectively) [14]. In 2015, the incidence and mortality from stroke in Yakutsk (Sakha Republic (Yakutia), Russia) were 3.64 and 0.83 cases per 1000 population per year, respectively [8].

Walking disorders are detected in about 80% of stroke survivors and significantly limit the patient's household and social activity, increase the risk of falls [5, 16]. Immediately after a stroke, 50% of patients cannot move independently, 12% of patients can only move with assistance, and after rehabilitation measures, the proportion of people able to walk independently increases to 50%, but 18% still have severe postural disorders. disorders [10]. Thus, motor rehabilitation of stroke patients is a key task.

The postural balance of a person is maintained by integrating incoming visual, vestibular, somatosensory, and proprioceptive information [9]. In addition, the cognitive sphere plays an important role in the control of movements [12]. In cerebral stroke, the breakdown of the above systems leads to the development of postural disorders [11]. A highly informative method for studying the balance function, based on the analysis of the parameters of the center of pressure (displacement along the sagittal and frontal axes, movement speed, statokinesiogram area, energy consumption), is stabilometry [4, 6]. In addition, using a stabilometric platform, it is possible to carry out dosed stabilotraining aimed at improving the patient's motor functions using biofeedback (BFB) [3, 13].

The aim of the study: clinical and stabilometric assessment of posture disorders in the complex rehabilitation of patients after a stroke.

Materials and research methods. This prospective study was conducted on the basis of the Department of Medical Rehabilitation of Patients with Functional CNS Disorders, Treatment and Rehabilitation Center of the Republican Clinical Hospital No. 3 (Yakutsk). All patients participating in the study signed an informed consent.

Criteria for inclusion: 1) the ability to maintain balance without support at the time of study and training; 2) no cognitive impairment (MMSE > 24 points); 3) the absence of severe somatic diseases that prevent the study.

Non-inclusion criteria: 1) inability to maintain balance without support; 2) cognitive impairments that impede the quality of understanding tasks and following instructions; 3) presence of neurodegenerative diseases of the nervous system, history of epilepsy; 4) cardiac and respiratory insufficiency, preventing the implementation of stabilometry and stabilotraining; 5) severe orthopedic disorders; 6) patients with only sensory disorders or without neurological symptoms; 7) patients with polyneuropathies of any etiology.

The study included 60 patients (40 men and 20 women, median age - 61.0 [56.25; 65.75] years, median period for the start of rehabilitation - 30.0 [25.0; 40.75] days). Depending on the neurological deficit, the patients were divided into 2 groups. The first group consisted of 30 people with hemiataxy; the second group - 30 people with hemiparesis. In each group, patients with ischemic and hemorrhagic stroke were equally divided.

All patients received treatment in accordance with current clinical guidelines and medical standards. The following scales and indices were used: NIHSS, Rivermead Mobility Index, Rankin Disability Scale, Barthel Daily Activity Index.

ARGUNOVA Oksana Gavrilievna – doctor of the Medical Rehabilitation Centre, the Republican Clinic No.3, Yakutsk, argunova1950@mail.ru; **TAPPAKHOV Aleksey Alekseevich** – PhD, associate professor of the Medical Institute of M.K. Ammosov NEFU, senior researcher of the Center for Neurodegenerative Diseases Yakut Science Centre of Clinical Medical Problems; **DMITRIEVA Natalia Gavrilovna** – head of the Medical Rehabilitation Centre, Republican Clinic No.3; **MAKAROVA Anna Nikolaevna** – head. Dept. Medical Rehabilitation Centre, Republican Clinic No. 3; **IVANOVA Maria Gennadievna** – student of the Medical Institute, M.K. Ammosov NEFU

Patients of both groups were comparable in terms of gender and age characteristics (p > 0.05). In patients of the 2nd group (with hemiparesis), the motor deficit was initially more pronounced according to the NIHSS scale (Table 1).

The stabilometric study was performed on the ST-150 platform (Mera, Russia) in accordance with standard recommendations [4]. Patients were examined before the first and after the last stabilotraining in the morning until 11 am, while any studies and procedures that could affect the result (for example, intravenous injections, fibrogastroscopy, etc.) were excluded. Stabilometry was carried out according to the European version of the installation of the feet (heels together, toes apart by 30°) in two phases (with open (EO) and closed (EC) eyes), each lasting 30 seconds. The following indicators of stabilometry were analyzed: the average position of the center of pressure (CP) along the sagittal (Y) and frontal (X) axes; area of the statokinesiogram (S); velocity CP (V), energic index (Ei).

Stability training with the use of BFB was carried out using the static test "Target" and the dynamic test "Hares" (Fig. 1). Each patient included in the study completed 10 workouts over 2 weeks (5 times a week) for 20 minutes (10 minutes for the Target test and 10 minutes for the Hares test). Training were carried out in the first half of the day, while the interval from the previous procedure (for example, massage, physiotherapy) was at least 30 minutes.

Statistical research methods. Statistical analysis was performed using the SPSS Statistics 22.0. Quantitative data are presented as median and 25th and 75th quartiles (Me [Q25; Q75]). For comparison of paired quantitative data, the Wilcoxon test was used; the Kruskal-Wallis test was used to compare four independent data. To level the lateralization of the process, the data module was analyzed by axial parameters (X, Y). To compare the dynamics before and after rehabilitation measures, the difference in indicators was calculated as a percentage. Spearman's test was used for correlation analysis. Spearman's test was used for correlation analysis. Differences were considered statistically significant at p ≤ 0.05.

Results. When evaluating stabilometry parameters in patients with both hemiataxy and hemiparesis, statistically significant improvements were obtained in the parameters of the statokinesiogram area, velocity CP, and energic index in both phases of the study. With hemiparesis, an improvement was also revealed in the

Table 1

Patient characteristics

Parameter	Group 1 (patients with hemiataxy) n = 30	Group 2 (patients with hemiparesis) n = 15	p-value
Median of age, years	62.0 [58.75; 68.0]	61.0 [53.0; 64.25]	0.182
Medain time to start rehabilitation after a stroke, days	27.5 [25.0; 39.25]	30.0 [25.0; 50.0]	0.219
Male / female, abs.	21 / 9	19 / 11	0.584
NIHSS, score	3.5 [2.0; 5.75]	6.0 [4.0; 8.0]	0.005*
Rivermead Mobility Index, score	11.0 [8.0; 13.0]	11.0 [7.0; 12.0]	0.549
Barthel index, score	85.0 [80.0; 95.0]	85.0 [71.25; 95.0]	0.403
Rankin scale, score	3.0 [2.0; 3.0]	3.0 [3.0; 4.0]	0.67

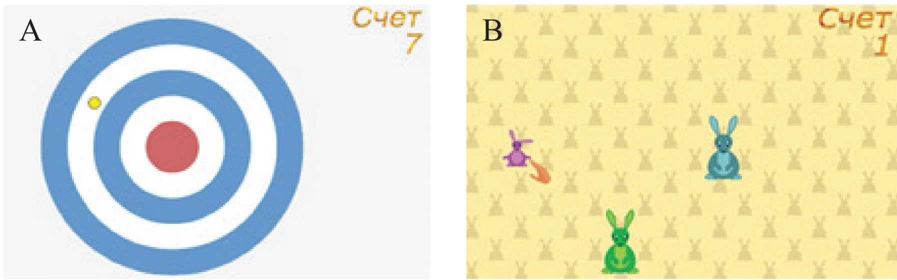

Fig. 1. Stability training: A - static test "Target", the patient, by shifting the center of the pressure, needs to move the yellow dot to the center of the target and hold it in this position for the maximum amount of time (until the end of the test series); B - dynamic test "Hares", the patient needs to move his hand by shifting the center of the pressure to capture the hares

Table 2

Summary results of stabilometry before and after complex rehabilitation

Sign	Significance before training	Significance after training	P-level
Group 1 (patients with hemiataxy)			
X (EO), mm	9.45 [2.35; 13.45]	9.35 [3.95; 16.73]	0.443
X (EC), mm	8.65 [2.58; 15.45]	8.2 [6.1; 18.9]	0.53
Y (EO), mm	10.05 [6.4; 20.75]	12.35 [5.45; 18.6]	0.853
Y (EC), mm	12.65 [3.95; 19.6]	15.3 [6.9; 23.63]	0.504
S (EO), mm²	594.95 [315.6; 941.03]	262.8 [224.0; 421.7]	< 0.001*
S (EC), mm²	1431.85 [694.48; 2393.1]	600.15 [295.95; 895.23]	< 0.001*
V (EO), mm/s	16.35 [15.1; 21.4]	14.15 [11.75; 16.25]	0.001
V (EC), mm/s	26.35 [21.71; 42.35]	20.15 [15.63; 24.85]	< 0.001
Av (EO), мJ/s	299.04 [173.44; 622.3]	167.12 [137.47; 372.63]	0.001
Av (EC), мJ/s	830.16 [475.31; 2283.0]	396.67 [210.53; 1191.36]	< 0.001*
Group 2 (patients with hemiparesis)			
X (EO), mm	6.95 [4.23; 13.95]	8.2 [4.65; 11.23]	0.984
X (EC), mm	7.0 [3.38; 12.75]	8.1 [5.42; 12.6]	0.472
Y (EO), mm	14.2 [8.73; 24.63]	9.3 [5.0; 19.8]	0.041*
Y (EC), mm	14.45 [8.8; 24.53]	12.25 [4.13; 22.23]	0.175
S (EO), mm²	465.1 [360.4; 657.65]	267.85 [186.95; 421.7]	0.003*
S (EC), mm²	766.8 [552.48; 1149.25]	413.55 [211.78; 740.73]	< 0.001*
V (EO), mm/s	10.8 [9.92; 17.2]	10.65 [8.55; 13.4]	< 0.001*
V (EC), mm/s	21.1 [16.56; 26.9]	14.53 [12.83; 21.0]	< 0.001*
Av (EO), мJ/s	175.47 [84.94; 323.62]	108.62 [72.82; 207.23]	0.004*
Av (EC), мJ/s	457.07 [243.9; 928.93]	253.93 [138.04; 573.8]	< 0.001*

* - statistically significant differences.

shift of the CP in the sagittal axis in EO phase, however, the p-value approaches 0.05 (p=0.041). Summary results of stabilometry before and after complex rehabilitation are presented in Table. 2.

We did not reveal differences in the degree of changes in stabilometric parameters in patients with different stroke syndromes (hemiataxia or hemiparesis) before and after complex rehabilitation (p > 0.05) (Fig. 2). However, patients with ataxia initially had statistically significantly larger statokinesiogram areas in the EC phase (p=0.005).

Left boxes - patients of the 1st group (with hemiataxy), right boxes - patients of the 2nd group (with hemiparesis). Abbreviations: CP, center of pressure; phase EO - phase with open eyes; phase EC - phase with closed eyes.

For all clinical scales and indices in all groups, statistically significant differences were obtained before and after complex rehabilitation (Table 3).

Correlation analysis did not reveal the dependence of the dynamics of changes in stabilometric parameters before and after complex rehabilitation on the age of patients, as well as on the time of the start of rehabilitation after a stroke (the maximum period is 129 days). There was no correlation between the dynamics of stabilometric parameters and the dynamics of assessments according to clinical scales (NIHSS, Rivermead mobility index, Barthel and Rankine scales) before and after complex rehabilitation. Before the start of complex rehabilitation, there was also no correlation between stabilometric parameters and clinical scales (p > 0.05), except for a moderate negative correlation between the area of the statokinesiogram in the EC phase and the total score on the Barthel scale in patients with ataxia (r = –0.468, p =0.01).

Discussion. We have shown the use of stabilometry to assess the effectiveness of complex medical rehabilitation,

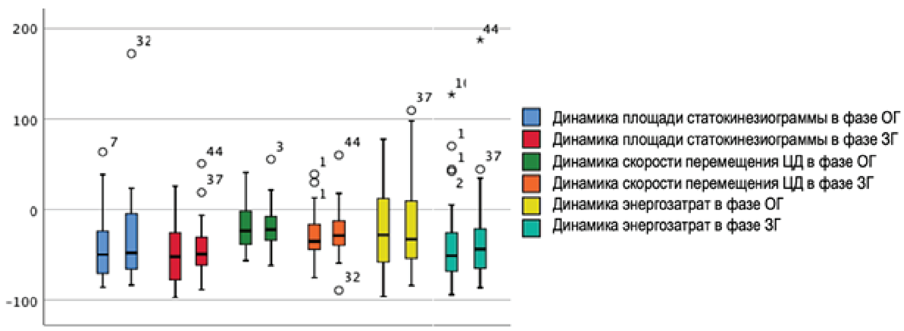

Fig. 2. Changes in stabilometric parameters before and after complex rehabilitation (in % of the initial level).

Table 3

Results of clinical scales and indices in patients of various groups before and after complex rehabilitation

Scales		Group 1	Group 2
NIHSS, scales	Before	3.5 [2.0; 5.75]	6.0 [4.0; 8.0]
	After	1.5 [0.0; 2.0]	3.0 [3.0; 4.0]
	p-value	< 0.001*	< 0.001*
Mobility index Rivermead	Before	11.0 [8.0; 13.0]	11.0 [7.0; 12.0]
	After	13.0 [12.0; 14.0]	14.0 [12.0; 14.0]
	p- value	< 0.001*	< 0.001*
Barthel scale	Before	85.0 [80.0; 95.0]	85.0 [71.25; 95.0]
	After	95.0 [90.0; 100.0]	100.0 [95.0; 100.0]
	p- value	< 0.001*	< 0.001*
Rankin scale	Before	3.0 [2.0; 3.0]	3.0 [3.0; 4.0]
	After	2.0 [2.0; 2.5]	2.0 [2.0; 3.0]
	p-value	< 0.001*	< 0.001*

incl. with the use of stability training, in patients with stroke and various neurological deficits (hemiparesis or hemiataxia).

Stabilometry is a highly informative method of objectifying imbalances; in addition, it can be used as biofeedback training in patients with movement disorders [2, 6]. Bronnikov V.A. and co-authors, on the basis of a stabilometric study of patients with stroke before and after rehabilitation, identified 4 variants of parameter changes that reflect different stages of the formation of a pathological stato-locomotor stereotype [7].

We did not set ourselves the task of determining the effectiveness of stability training in the complex rehabilitation of patients with cerebral stroke, since a number of studies have already been devoted to this. A study by Walker C. and colleagues in the early 2000s compared physiotherapy and physiotherapy in combination with biofeedback training in patients with hemiparesis after a stroke. 46 patients who had a stroke within 80 days were included. BFB trainings were held daily for 30 minutes a day until discharge from the hospital. As a result of the study, scientists did not find significant differences in the improvement of motor functions in the two groups and concluded that biofeedback training does not provide benefits in the early rehabilitation of patients with stroke [18].

Barkala L. and colleagues studied the effect of biofeedback balance training in patients with hemiplegia after a stroke. The main group received training using the Nintendo Wii Fit biofeedback system in a playful way along with traditional physical therapy, while the control group received only physical therapy. Training was carried out for 5 weeks, 2 sessions per week for 30 minutes. Scientists did not find a statistically significant difference in the two groups in terms of body symmetry (baropodometry), static balance (stabilometry) and functional independence and concluded that the improvement was achieved through physiotherapy [17].

The effect of biofeedback training on stroke recovery in a later period (more than 3 months) was shown by Srivastava A. and colleagues. A study that included 45 post-stroke patients (mean 16.51± 15.14 months) and 20 sessions of biofeedback training (20 min per day, 5 days per week, for 4 weeks) found statistically significant differences according to the Berg balance scale, functional status and Barthel index [15]. The successful use of stabilometric training using BFB in combination with functional electrical stimulation in the late recovery period of ischemic stroke was also demonstrated by domestic scientists who conducted training every other day for 5 weeks (15 procedures in total) [1].

Virtual reality technologies have advantages over traditional rehabilitation measures in patients with cognitive decline and motor deficits. This was shown in individuals with cerebral palsy, who showed greater interest, initiative, learning ability and higher motivation when using virtual reality technologies in rehabilitation [19].

The difference of our study is the assessment of stabilometric parameters in patients with various post-stroke syndromes (hemiataxia or hemiparesis). In both groups, we obtained statistically significant improvements in all stabilometric parameters, except for the parameters of the support symmetry (displacement of the CP in the frontal and sagittal axes).

Although improvements were obtained in the process of complex rehabilitation in all clinical scales and indicators, we did not find a significant relationship with stabilometric indicators both before and after rehabilitation. In our opinion, this is due to the different sensitivity of clinical scales and stabilometry to assess the balance function.

The limitations of our study are the lack of consideration of cognitive functions for balance and the outcome of rehabilitation (patients with moderate and severe cognitive impairment were not included in the study). We also did not take into account neuroimaging data (volume, location of ischemia or intracerebral hematoma).

Thus, stabilometry is a highly informative method for studying the balance function in patients after a stroke in complex rehabilitation, however, the lack of correlation of parameters with clinical scales should be taken into account. Further studies may be aimed at identifying the role of cognitive impairment in the process of complex rehabilitation of patients after a stroke using stabilometry.

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