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Neurorehabilitation of poststroke cognitive impairments with the use of computed programs

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Abstract - **The purpose of the present research was the estimation of efficiency of new methods of neurorehabilitation of impairments of cognitive functions with the use of computer programs of correction. Twenty six post-stroke patients aged 57-69, (male - 12, female - 14) were examined and treated. In addition to usual restorative treatment all patients received a course of neuropsychological computer programs training within 14 days, 25-35 min of duration. Tasks included training of attention with use of the computed programs on the basis of Schulte's test, the task for training visual storing with a set of pictures and symbols, the switching test, correction optical and spatial gnosis with test of narrative images and the test of «arrangements of hands of the clock» with possibility of a feedback. Initial level cognitive impairments and results of restoration were estimated with the use of Mini Mental State Examination, Frontal Assessment Battery, the Clock Drawing Test, the Montreal Cognitive Assessment, Schulte's test. The first experience of inclusion of the computed programs of correction of cognitive impairments in schemes of neurorehabilitation has shown good effect concerning clinical displays, and concerning Patient Global Impression Scale. Although the results are encouraging, further studies are required with larger samples and longer follow-up to identify characteristics of those patients who are most likely to benefit from computed training of cognitive functions.**

Keywords- neurorehabilitation, stroke, cognitive impairments, computed programs of correction

I. INTRODUCTION

The statistics of scientific researches of the last decade was marked by a considerable number of research devoted to vascular cognitive impairments and vascular dementia [1]. As a result the frequency of occurrence of cognitive impairments after a stroke (20 - 30 %) was estimated, development risk factors were proved [1,2], and also the correlation between presence of post-stroke dementia and increase in risk of a repeated stroke and risk of death [1-3] was revealed.

The most frequent displays of vascular cognitive impairments are attention disorders, emaciation, disorder of executive functions, regulatory memory disorders. In the studies, (which concern) on infringements of attention, it is shown, that in the result of this pathology the efficiency of cognitive activity decreases despite lack of primary disorders of the higher cortical functions. This fact can be the key in restoration of specified disorders [4]. Robertson et al. have shown, that presence of steady attention by 2nd month after a stroke is a positive predictor of full restoration of cognitive functions [4]. Nys [5] has proved that A degree of impairments of cognitive functions in one week after a stroke is a predictor of the quality of life in half a year after the stroke (according with Stroke Impact Scale), thus presence of an unilateral visually-spatial inattention is statistically significant. According to other authors, distractibility and attention play a role in impairments of balance and daily functioning, including physical and social aspects of it [4]. Deficiency of attention is connected with the big functional disorders and falls at post-stroke patients at homes for the elderly. [6]

At the same time vascular cognitive impairments have usually small rate of progression («the stable answer on placebo») [7].

Results of the numerous studies, concerning symptomatic treatment of vascular dementia, were published, including anti-thrombocytic preparations, nootropics, analogues of thyrotropin-releasing hormone, extract of gingko biloba, preparations influencing stickiness of plasma, hyperbaric oxygenation, antioxidants, serotonin and histamine receptor antagonists, vasoactive substances, preparations of xanthine group, antagonists of calcium [8]. These studies have mainly shown negative result that is connected with small number of research groups, the short period of treatment, absence of uniformity in diagnostic both estimated criteria and final points. Anyway, there is no any proven symptomatic therapy of vascular cognitive impairments at present. In therapy of vascular dementia such preparations as memantine [9] and anticholinesterase agents [10] have shown their efficiency.

The potential purposes in treatment of vascular cognitive impairments are: 1) symptomatic improvement of cortical functions (cognitive disorders, functioning and behavior level), 2) decreasing of progression degree, 3) treatment of neuropsychiatric symptoms (depression, psychic tension, agitation) [8].

According to ESO2008, now there are no sufficient proofs concerning specific rehabilitation of memory [11]. The exercises directed on restoration of deficiency of attention, have not led to the considerable positive results, which influence improvement of a clinical picture and daily life activities. In a randomized controllable research of 84 patients who survived after a stroke, the estimation of attention training was carried out with the purpose of restoration of ability to drive a car. Research concentrated on elimination of visual ignoring and had no sufficient statistical significance [12]

In research of 16 post-stroke patients in comparison with 13 patients of the control group the attention retraining improved attention, neglect, and speed (evaluated with an on-road driving evaluation, visuoperception tests, and the test of everyday attention) [13]. Unfortunately, it was nonrandomized, small, had no remote estimation of results and differed by non-uniform control group. Use of the computerized programs of attention training is estimated in randomized controllable research of 27 patients with unilateral hemisphere damage, basically caused by the insult [12] Trainings improved sharpness and stability of attention, but, unfortunately, sample was small, quality of life was not estimated, and inclusion of patients with a craniocerebral trauma and big distinctions between groups by intervention level made the received data insufficiently reliable. The Cochrane review, which is based on 2 small controllable researches of attention deficiency training after stroke, has concluded the following: big sample and blinded randomized researches are required [4].

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According to ESO2008 recommendations, exercises aimed at correction of anosognosia (spatial neglect) improve disease state, but efficiency for ADL has not been shown [14]. Some studies estimated efficiency of the exercises aimed at visual disorders and apraxia, but specific conclusions have not been made [15].

At present, there is no best practice of correction of the cognitive disorders with the use of trainings, which are based on specially developed computer tasks. The studies are known [16], which prove application potential of computer games for complex rehabilitation and increase of motivation to motor exercises. However, differentiated computer programs have not been used for cognitive stimulation before, so in this connection we have created special programs of computer correction of the cognitive disorders, which are based on assignments for neuropsychological testing, where variants and complexity of tasks can be changed in conformity with abilities of a patient.

The purpose of the present research was the estimation of efficiency of new methods of neurorehabilitation of impairments of cognitive functions with the use of computer programs of correction.

II. SUBJECTS AND METHOD

A. Contingent of patients

The patients, who are on a stationary course of neurorehabilitation in the Siberian Clinical Center of Federal Medical and Biological Agency, participated in research. The patients who have suffered hemisphere stroke with cognitive impairments in stage mild cognitive impairments and mild dementia, without significant speech pathology and epilepsy in the acute and early restorative period of a stroke. 40 persons were randomized in the basic and control groups. The basic group is presented of 26 patients at the age of 60-72 (Median = 61 [57; 69]) years, control –14 persons - at the age of 60-72 (Median 66 [61; 69]) years. Individuals were excluded if they could not give informed consent; experienced severe cognitive deficits precluding participation (Mini Mental Status Exam [MMSE] <20), were medically unstable, were not fluent in Russian as required for standardized assessment, or had another condition that could impact results (e.g. aphasia). Stroke survivors were approached within 2 weeks after stroke.

B. Procedure

1) Diagnostics methods.

All patients, besides detailed clinical-neurologic research, passed an estimation of the neurologic status according to the scale of stroke NIHSS. The Scale of Stroke of National Institutes of Health (National Institutes of Health, or NIH, Stroke Scale) allows estimating of basic spheres of the neurologic status: general brain symptoms, function of craniocereberal nerves, motorial, sensitive and coordinatory systems, as well as speech status. Intensity of symptoms fluctuates from 0 to 3-4 points, from normal rates to complete loss of function. The internal consistency and re-testing reliability are proved by a number of researches (Goldstein J.C. et al, 1989).

Validation of localization and character of the brain lesion focus was carried out by method of the routine MRT. Absence of epileptiform activity was established by results of the computer electroencephalography. Estimation of the condition of cognitive sphere was carried out with the use of the standard tests in neurologic practice: MMSE - widespread test used for screening of patients and estimation of dementia severity; FAB – test battery for estimation of cognitive disorders of mainly subcortical and subcortical-frontal type; Clock drawing test - is sensitive to revealing of disorders of optical-spatial gnosis and executive functions; Montreal Scale of Cognitive Assessment (MoCA) - as a means of fast estimation at moderate cognitive dysfunction. The estimation of attention disorders was carried out with the use of Schulte's tables. The test is a validated technique for estimation of concentration and switching of attention and represents itself tables five on five squares (cells), in which figures from 0 to 25 are placed. A patient is offered to find and show, as soon as possible, all figures in increasing order. Standard values of full completion correspond to 40-45 seconds. At decrease in attention the time for task performance is extended.

The estimation of emotional-volitional disorders is carried out according to HADS scale - simple screening-questionnaire for revealing of the signs of anxiety or depression. The estimation of daily activity with the use of IADL scale, which allows assessing of basic displays of life activity – ability of independent walking, feeding, travelling, carrying out of hygienic procedures, shopping and etc.

The estimation of satisfaction with results of treatment by clinical physician was carried out according to CGIS scale, where efficiency of therapy was estimated by clinical physician on a 1-5 scale: -1 - symptoms have worsened, 0 - without changes, 1 limited improvement, 2 - considerable improvement, 3 - symptoms were completely jugulated. Also the PGIS scale for assessment of patient's satisfaction with results of treatment was used - the same questions were answered by a patient personally.

C. Treatment methods

Except standard treatment of in-patient rehabilitation department, participants in the basis group received up to 30 hours of individual training with use of computed programs conducted for 30 minutes on weekdays for 2 weeks. Patients in the control group received up standard treatment of in-patient rehabilitation department**.**

1) Essence of the training computed programs method

a) Training of attention with use of computed Schulte's tables

We have developed a method of restoration of the 4 aspects of attention (ie, sustained, selective, divided, alternating) on the basis of a computed variant of Schulte's tables with feedback and "help" possibility.

The training consists in the following: Schulte's table is presented to the full screen of the monitor of the computer by the big square from 25 cages (5*5) in which in a casual order there are numbers from 1 to 25. During the training a patient should find numbers from 1 to 25 in a chronological order, bring the cursor and the left button of the mouse to specify corresponding number. The task is made for time (Fig. 1).

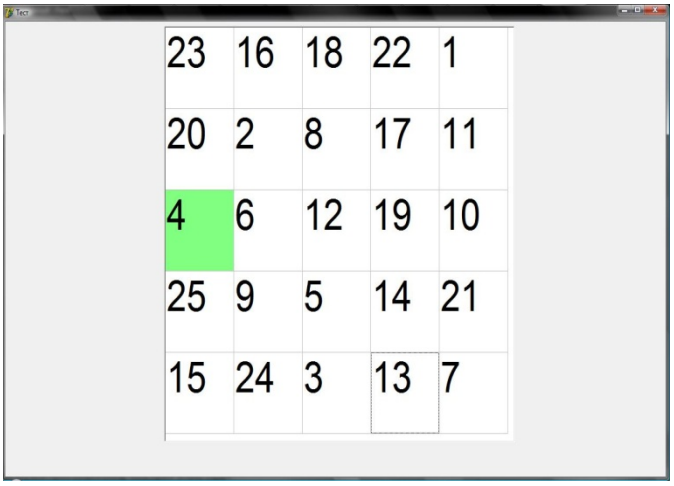

Figure 1. On the computer screen computed variant of Schulte's tables is presented. Contrast light illuminates figure which is required to be found to the patient.

In case the patient cannot find actual number during set time, it is highlighted by distinctive color and the size of figure (the actual number pulses) changes. The indication on the actual number with the left button of the computer mouse returns it in a normal view that allows to continue task performance. The allowed time for a search of one figure, can vary depending on degree of infringements of attention of the patient and could be set up by the instructor. At the end of the training the time spent for performance of the task is presented on the monitor screen. It should be mentioned, that execution of tasks wasn't aimed at evaluation of the cognitive functions, but at training of these functions; though speed of task performance was measured in seconds after the game, it served a patient only as a reference point for attention improvement. Efficiency of the conducted treatment course was estimated upon expiration of supervision period with the use of validated scales represented in "Methods" section. We had provided possibility of difficulty level correction of a task by changing interval for patient's own reflection before appearance of a hint in the form of highlighting of the correct figure with alternative colour.

b) Training visual-spatial gnosis with use of the computed test "figure-background".

The method of the training of the visual-spatial gnosis on the basis of a computed variant of test "figure-background" with possibility of a feedback and a gradually decreasing in degree of intensity of background noise is developed.

The training consists in the following: the picture image with decreasing intensity of background noise is presented in the full screen of the computer monitor in the big square. There are several different pictures without background in the top part of the screen one of these pictures corresponds to the image presented in the task with noise, other pictures represent various images of subjects and letters. During the training session the patient should indicate with use of the mouse cursor on that image in the top part of the screen which corresponds presented in the task with noise. There is a gradual reduction of intensity of noise, up to full disappearance of it. The task of the patient – to recognize, what image is present as soon as possible. Speed of a recognizance is designated by points from 0 to 10. Correctness of performance is marked by an applause or a signal "incorrectly" (Fig. 2).

Figure 2. The picture image with decreasing intensity of background noise is presented in the full screen of the computer monitor in the big square. There are several different pictures without background in the top part of the screen one of these pictures corresponds to the image presented in the task with noise.

c) Training of visually-spatial memory with use of tests with storing of position of a picture

The essence of the task consists in storing of an arrangement of gradually increasing numbers of subjects (books) in cells of table 4 X 5 (Fig. 3).

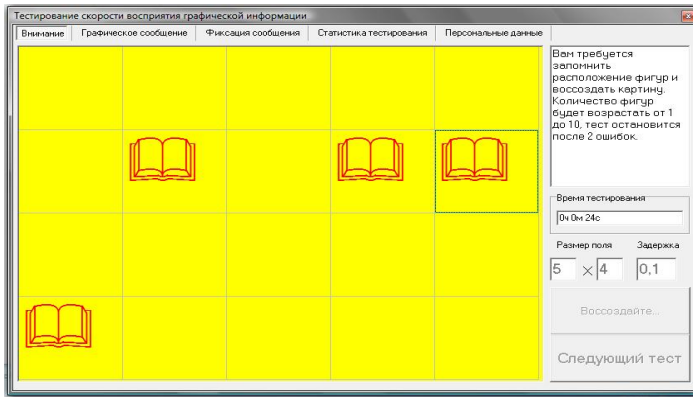

Figure 3. Training of visually-spatial memory.

After demonstration of pictures, which were arranged in cells, they were hidden for some seconds, and a patient was given the task to show by mouse cursor in what of cells there were subjects. After correct performance the number of subjects for memorizing was increased by 1. The task is carried out by a patient before making of 2 mistakes, upon which information about speed of answer and correctness, as well as what is the highest volume of the information was memorized by a patient, is displayed on the screen.

Except the listed tests, in complex of methods of computed correction of cognitive impairments entered the computed tasks «storing of series of symbols», «arrangements of hands of the clock», and «the serial count».

Essential result of the offered techniques is:

- The program can be used for correction different cognitive impairments, including attention;
- Possibility of actualization of "game" motivation in patients (registration of the test in the form of game), that makes the rehabilitation process more attractive, raising efficiency of regenerative treatment;

- Simplicity in use. The doctor of the general practice, physiotherapist, nurse or relatives of the patient can spend these training.
- There is a possibility of regulation of degree of loading
- Various didactic equipment (excludes necessity in numerous cards and other didactic material).

III. Statistical Analyses

For the analysis of data the package of applied programs of the STATISTICA 8 was used. All of the clinical variables listed before were estimated with use of Normality Testing, Descriptive Statistic. Median and the 25,00 and 75,00 quartiles were found for all Nonparametric Variables. Differences in the groups were compared among the basis and the control groups with use of Nonparametric statistic of Kolmogorov-Smirnov Test prior and after the treatment. Differences in cognitive, emotional, daily activity sings between the dependent group (basis group before and after the treatment, control group before and after the treatment) were performed with use of Nonparametric statistic of Wilcoxon Matched Pairs Test. Alpha for statistical significance was $p < 0.05$.

IV. Results

Results were estimated in day of inclusion in research, assessments were repeated at 14-16 day by trained assessor blind to randomization.

Initial estimation showed that degree of impairments of cognitive functions in patients of the both groups varied from moderate cognitive impairments to mild dementia. Results of cognitive testing prior to the beginning of treatment had no statistically significant distinctions between the basic and control groups (Kolmogorov-Smirnov Test, p>0,1) and are presented in the tab. 1.

TABLE I. Results of cognitive testing prior to the beginning of treatment in the both group

Scale Normal values	MMSE 28-30	FAB 18-20	MoCA 25-30	Clock drawing test 10	Shulte's test Less then 45 sec
Basic group Median, [25;75]	24 [24;26]	15 [14;16]	21 [19;21]	7,5 [7;9]	81 [61;134]
Control group Median, [25;75]	24,5 [23;26]	15,5 [14;17]	19,5 [17,5;22]	8,5 [6,5;9,5]	89 [72;110]
Indicator p, Kolmogorov -Smirnov Test	p>0.1	p>0.1	p>0.1	p>0.1	p>0.1

Degree of infringements of quality of live before the training with use of correctional computed programs on scale SS-QOL-2 has made 151 [134; 180] – in basic group and 153,5 [142; 163] in control group (maximum value is 245 – "no help needed"). The anxiety and depression levels, estimated with the use of HADS were in basic group A = 6 [4; 8] - norm, D=7 [3,7] - subclinical expressed depression, in control group - A=8 [5; 9] - subclinical expressed anxiety, D=8 [5; 10] - subclinical expressed depression. Statistically significant differences between basis and control groups prior to treatment in anxiety and depression levels were not revealed (Kolmogorov-Smirnov Test, p > 0,1).

There were significant improvement of cognitive function according with MMSE, FAB, Clock drawing test, Schulte's test, Montreal Cognitive Assessment ($P<0.01$) in basis group (Tab.2). The indicators of control group testing were not revealed significant changes ($P>0.06$) after the treatment course (Tab.3). Difference in change was not significant for IADL and SS-QOL2 assessments administered. Probably, it is connected with the short period of treatment and the small size of sample.

Degree of expressiveness of anxiety and depression after completing of therapy has not undergone statistically significant changes in the basic and control groups: in basic group T=6 [5; 8], Д=3 [2; 8] - clinically insignificant level of anxiety and depression; in control group T=8 [5; 10], - subclinical expressed anxiety, D=6,5 [4,5; 8,5] - norm.

Satisfaction of patients of results of treatment considerably differed in the basis group, there it was presented in all cases by «considerable improvement» while in control group satisfaction of patients was low and presented «absence of improvements» in the number patients.

TABLE II. Changes in cognitive function according with MMSE, FAB, Clock drawing test, Schulte's test, Montreal Cognitive Assessment in basis group after the treatment

Scale Normal values	MMSE 28-30	FAB 18-20	MoCA 25-30	Clock drawing test 10	Shulte's test Less then 45 sec
Basic group prior to treatment Median, [25;75]	24 [24;26]	15 [14;16]	21 [19;21]	7,5 [7;9]	81 [61;134]
Basic group after the treatment Median, [25;75]	27 [26;28]	17 [16;18]	25 [23;27]	9 [8,5;10]	61 [55;78]
Wilcoxon Matched Pairs Test	p=0,01	p=0,017	p=0,007	p=0,027	p=0,007

TABLE III. Changes in cognitive function according with MMSE, FAB, Clock drawing test, Schulte's test, Montreal Cognitive Assessment in control group after the treatment

Scale Normal values	MMSE 28-30	FAB 18-20	MoCA 25-30	Clock drawing test 10	Shulte's test Less then 45 sec
Prior to treatment Median, [25;75]	24,5 [23;26]	15,5 [14;17]	19,5 [17,5;22]	8,5 [6,5;9,5]	89 [72;110]
After the treatment Median, [25;75]	26 [24;28,5]	17,5 [16;18]	21,5 [20;23,5]	7,5 [6;9]	89,5 [72;112,5]
Wilcoxon Matched Pairs Test	p=0,6	p=0,13	p=0,13	p=0,9	p=0,6

V. CONCLUSIONS.

The first experience of inclusion of the training with the use of computer programs of correction into schemes of neurorehabilitation has shown good effect concerning both clinical aspects and the Patient Global Impression Scale. In our opinion, the given direction of neurorehabilitation can be promising because of ease of use and possibility of independent application by patients, even without immidiate involvement of the medical personnel. In distinction from computer games for general development, the present method allows correcting purposefully of suffering neuropsychological functions. Further studies are required for higher statistical significance of the obtained results.

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