The Dynamics of Serial Construction of Movements in Rehabilitative Training of Young Patents Who Had Ischemic Stroke

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Abstract- The article presents the results of the study of the dynamics of serial construction of movements in the rehabilitative training of young patients who had ischemic stroke. The research sample consisted of 34 patients of young age (27-42 years old) who had an ischemic stroke of hemispheric localization for the first time. According to the criteria of localization of the stroke (in the leading or non-leading hemisphere) and the lateralization profile, four research groups were formed. The research methods included a set of functional neuropsychological samples aimed at studying the functions of praxis, as well as hardware methods of diagnosis and rehabilitative learning.

As a result of preliminary assessment of the parameters of locomotor and voluntary levels of movement construction in young patients who had ischemic stroke, the disorders of motor skills characterized by specific manifestations depending on the lateralization profile and hemispheric localization of the impact site were revealed. The organization of the contents of rehabilitative training program in young patients who had ischemic stroke was carried out with respect to all specific manifestations of motor functions disorders. The most intensive dynamics in rehabilitative training of young patients who had ischemic stroke was detected in left-handed patients with impact site localization. The minimal effect of rehabilitation of serial organization of movements is noted in right-handed patients of young age who had an ischemic stroke with localization of the impact site in the leading (left) hemisphere.

The practical relevance of the empirical results is following: after completing the program of rehabilitation education by young patients who had ischemic stroke, regardless of the hemispheric location of the impact site and the lateralization profile, it was reliably confirmed that serial organization of motor skills, which forms the basis for the formation of self-service skills, was successfully recovered.

Keywords: ischemic stroke, patients of young age, serial organization of motor skills, rehabilitation training.

1 Introduction

According to statistical reports over the past five years, Russia shows a stable trend regarding the increase of newly reported cases of ischemic stroke [1]. At the same time, it is obviously a positive trend that there is a steady decline in mortality from cerebrovascular diseases, including a cerebral infarction. The trends indicate a significant increase (more than two times) in patients belonging to the zone of active rehabilitation and recovery procedures.

Modern strategies and directions of rehabilitation measures are focused on solving problems of rehabilitation of locomotion and basic motor functions of the lower limbs (walking) [2,3] and upper limbs [4]; fine-motor functions [5]; application of virtual technologies in the rehabilitation training [6]; as well as the multi-profile rehabilitation effects with the involvement of specialists of various profiles [7].

The leading role in the ischemic stroke manifestations is played by impaired motor functions, which, in turn, play a leading role in the social adaptation of patients. According to modern ideas, the organization of motor functions has a hierarchical structure, represented by the reflex, locomotor and voluntary levels of movement construction. At the morpho-functional level, the implementation of these levels of movement construction is provided by three functional brain units, described by A.R. Luria: energy unit (including subcortical, median, cortical medobasal morphofunctional brain systems); a receiving, processing and information storing unit (including the posterior convexital sections of the cortex of the cerebral hemispheres); programming, regulation and activity control unit (including the frontal cortex of the cerebral hemispheres) [8]. The disorder of the reflex level of the movement construction is correlated with changes in the functioning of brain's energy block. The functioning of the locomotor level of movement construction is related to the changes in receiving, processing and information storing unit. The functioning of a voluntary level of movement construction is provided by programming, regulation and activity control unit [9,10].

The purpose of the research is to study the dynamics of serial construction of movements in the rehabilitative training of young patients who had ischemic stroke.

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2 Methods

Total sample size of the research was 34 patients aged 27-42 (with average age 36.2 ± 2.49 years) – first-time sufferers of an ischemic stroke with an early period of hospitalization. At the time of the research, all subjects were at the rehabilitative stage in the early recovery period at the sanatorium. The basis for the inclusion of subjects in the research groups was hemispheric localization of ischemic stroke impact site: 18 patients with localization of the impact site in the left hemisphere; 16 patients with localization of the impact site in the right hemisphere. Confirmation of the localization of the impact site and the nature of the stroke was carried out using neuroimaging methods (computer and / or magnetic resonance imaging).

The evaluation of the neurological status of young patients who had ischemic stroke was performed using the following scales: NIHSS (National Institute of Health Stroke Scale) and MMSE (Mini-mental State Examination).

At the preliminary stage of the research the evaluation of lateralization profile was conducted in order to differentiate the sequence of rehabilitation and recreative treatments for young patients who had ischemic stroke, with due consideration of hemispheric localization (in leading or non-leading hemisphere). To assess the profile of lateralization, the method of automated research of an individual lateral profile was developed – it was based on the method of functional biofeedback [11]. Lateralization profile was determined by the prevalence of left-sided or right-sided indicators. A group of left-handed subjects included patients who had scores of 51% or more in the three scales of the preliminary and three scales of the main evaluation in left-sided indicators. The group of right-handed subjects included patients who had ischemic stroke with right-sided indicators exceeding 51% in three scales of preliminary and three scales of the main evaluation.

According to the criteria of hemispheric localization of the impact site and the lateralization profile of young patients who had ischemic stroke, four research groups were formed: 1) right-handed patients with localization of the impact site in the leading (left) hemisphere - 12 subjects (RL); 2) left-handed patients with localization of the impact site in the leading (right) hemisphere - 6 subjects (LR); 3) right-handed patients with localization of the impact site in the non-leading (right) hemisphere - 10 subjects (RR); 4) left-handed patients with localization of the impact site in the non-leading (left) hemisphere - 6 subjects (LL).

The organization of the research was carried out consistently in three stages. The objective of the ***first stage*** was to estimate the initial level of motor function indices at the reflex, locomotor and voluntary levels, taking into account the hemispheric localization of the impact site and the lateralization profile. To study the motor skills at the reflex level, the elimination of spinal disorders was used. The evaluation was carried out in the carpi radialis reflex of the upper limbs; tendon reflexes with the biceps and triceps muscles of the upper limbs. All patients who were included in the study groups had unconstrained reflex status. The study of the locomotor level of movement construction was carried out by means of assessing the possibility of maintaining the posture of the body (sitting); orientation of one's own body in the space (top-bottom, right-left). The study of a voluntary level of movement construction was carried out using a set of functional neuropsychological tests aimed at assessing the kinetic, kinesthetic, spatial and dynamic praxis. Evaluation of the results of performing functional neuropsychological tests aimed at investigating the functions of praxis (according to the criteria of tempo, accuracy and coordination) was carried out on a 4-point scale (L.I. Vasserman) (Table 1).

Criteria	Accuracy	Tempo	Coordination
0 points	Full completion of the task	Stability of the task execution tempo	Correct execution of separate operations and actions; correct position of the hand relative to the work space
1 point	Minor errors in completing the task, which are independently corrected by the examinee	Uneven tempo of task completion (alternating acceleration and slowing the tempo)	Single errors in completing individual operations that are self-corrected
2 points	Disorder of the program for performing certain operations (skipping, duplication, substitution of operations)	Acceleration of the tempo, long pauses in the transition to the next operation	Errors in the execution of separate operations are not corrected, which leads to a distortion both of the task execution process and its final result
3 points	Inability to perform a specified sequence of actions	Acceleration the task completion tempo leading to the impossibility of singling out individual operations; long pauses leading to the impossibility of further execution.	Rough errors in execution of separate actions and operations leading to the impossibility of completing the task

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Table 1 Criteria for evaluating the results of performing tasks on the study of voluntary movements

Statistical processing of empirical results at this stage was carried out using nonparametric Mann-Whitney U-test ($p<0,05$) through a pairwise comparison of four groups of young patients who had an ischemic stroke prior to rehabilitative training.

The **second stage** used a program of rehabilitative training which involved software and hardware complex based on machine vision method. The automation of the procedure includes voice support and elements of gamification. The software is designed for Windows 7.8. NET Framework 4.0, 4.5 operating systems and is based on JAVA language. In the process of application "Visual Medicine" complex, the accuracy and tempo of task execution was recorded, as coordination of actions and the dynamics of the recovery process [13].

From the technological point of view, the program of rehabilitation training for the serial construction of movements in young patients who had ischemic stroke included activation of two levels of movement construction: locomotor and voluntary levels.

The procedure and methodology of rehabilitation training for the serial organization of motor skills of young patients who had ischemic stroke at the locomotor level included: rhythmic flexion / extension of the wrist and elbow joints with an increase in rhythm (with assistance; modeled, independent); hand movements with the imitation of a step in several variants (left leg - left arm, right leg - right arm, left leg - right arm, right leg - left arm); rhythmic flexing / extension of the fingers (separately with the left hand, right hand, two hands simultaneously). At the voluntary level, the procedure and methodology of recreation training for the serial organization of patient movements included: the fulfillment of a given research program (serial organization of movements with visual-sensory control, serial organization of movements with auditory-sensory control); the formation of the motor program (the independent formation of the motor program through the verbalization of the sequence of actions corresponding to the skills of self-service, the execution of verbalized sequence of actions with one hand, then with the other hand, then with both hands simultaneously).

Total duration of the rehabilitative training program for young patients who had an ischemic stroke was 20 days. Periodicity of lessons: two lessons a day – in the first and second half of the day. The duration of training in the process of rehabilitation training increased: day 1 – 10 it was 10-15 minutes; day 11 – 20 the duration increased to 15-25 minutes.

Each lesson in the rehabilitative training program included the sequential activation of locomotor and voluntary levels of movement construction. At the locomotor level, young patients who had an ischemic stroke had to perform basic motor movements in the form of rhythmic flexion / extension of the wrist and elbow joints; movement of hands with the imitation of a step; rhythmic flexion / extension of fingers first with one hand, then with the other hand – first they did it with assistance, then they used visual sample, then they did it independently.

Activation of the voluntary level of movement construction in the process of rehabilitative training presupposes serial construction of movements that make up the motor program. Initially, patients were asked to reproduce the given serial sequence of movements (fist-edge of the hand-palm, fist- edge of the hand -ring) with the help of visual-sensory control. Then the procedure was repeated, but with auditory-sensory control. In order to independently form the motor (manual) program, patients were first required to verbalize the sequence of actions corresponding to the skills of self-service; then the verbalized sequence of actions was carried out first with one, then with the other hand, then with both hands simultaneously.

The objective of the **third stage** was a comparative evaluation of motor function at locomotor and voluntary levels in young patients with ischemic stroke, taking into account the hemispheric localization of the impact site and the lateralization profile before and after the rehabilitative training program. After the completion of the rehabilitative training program, a comparative evaluation of the indices of voluntary level of movement construction was performed for each group of young patients who had an ischemic stroke before and after completing the rehabilitative training program using a nonparametric $\chi 2$-Friedman criterion ($p<0.05$).

3 Results And Discussion

As a result of the study of locomotor level of construction of movements in young patients who had an ischemic stroke, the retention of the sitting posture for 10-12 minutes was discovered – regardless of the hemispheric localization of the ischemic stroke and the lateralization profile. The reduction of accuracy of the right-left orientation in the space has also been discovered. Besides, at the locomotor level, with the damage of the leading hemisphere – regardless of the lateralization profile – the disorder of the rhythm of flexion / extension of the wrist and elbow joints was revealed, as reflected in a decrease in the movement tempo. It should be noted that the greatest difficulties arise when performing actions by the leading hand in comparison with the non-leading one. When performing hand movements with a step simulation in various combinations (left leg - left arm, right leg - right arm, left leg - right arm, right leg - left arm), patients of young age who had an ischemic stroke, regardless of the hemispheric location of the impact site and the profile of lateralization, had no difficulties with performing the tasks. Rhythmic flexion / extension of the fingers is characterized by a decrease

in the tempo and accuracy of execution, regardless of the hemispheric location of the ischemic stroke site and the lateralization profile of young patients who had an ischemic stroke.

When making a comparative evaluation of the manifestations of the locomotor level of the movement construction in young patients who had an ischemic stroke – with due consideration of the hemispheric localization of the impact site and the lateralization profile – it was discovered that the most severe form of disturbances is manifested in right-handed patients with localization of the impact site in the leading hemisphere of the brain. The minimum degree of severity of locomotor movement disorders is discovered in young left-handed patients with localization of the impact site in the non-leading hemisphere of the brain.

As a result of evaluation of voluntary level of movement construction in all young patients who had ischemic stroke – regardless of the hemispheric location of the impact site and the lateralization profile – the disorder of voluntary level of movement organization by the criteria of tempo, accuracy and coordination was discovered.

When performing neuropsychological tests aimed at studying the functions of praxis (kinetic, kinesthetic, spatial, dynamic), it was discovered that the greatest difficulties in reproducing the poses of the fingers of the hands both in the visual and kinesthetic samples arise in right handed patients of young age with localization of the impact site in the leading (left) hemisphere. When reproducing poses on the side, which is contralateral to the impact site, the patients use another hand to perform the task. With the damage of the non-leading hemisphere, regardless of the lateralization profile, the fixation of a given posture was performed by a search method (Fig. 1).

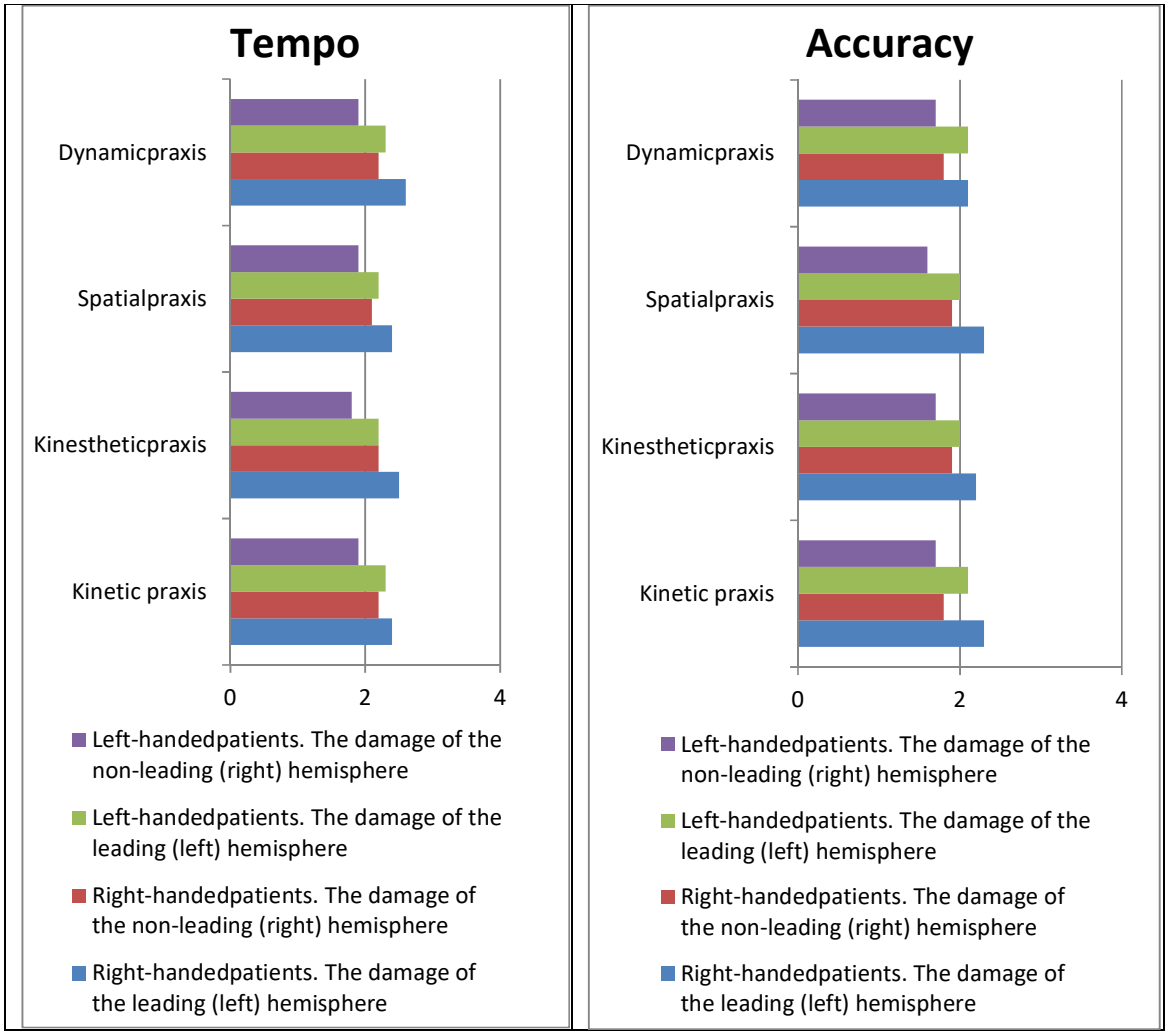

Fig. 1. Histograms of average values of tempo and accuracy of praxis functions in young patients who had an ischemic stroke, with due consideration of hemispheric localization of the impact site and the lateralization profile before rehabilitative training.

All patients of young age who had an ischemic stroke made mistakes in the accuracy of the right-left orientation and showed a decrease in the tempo of task completion. The malfunction of dynamic praxis in young patients

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who had an ischemic stroke with localization of the impact site in the non-leading hemisphere is manifested in synchronous (simultaneous) execution of the actions with the right and left hand. When localization of the impact site in the leading hemisphere in young patients who had an ischemic stroke – regardless of the lateralization profile – the malfunctions were detected in completing given motor program involving the serial organization of movements ("fist-edge of the hand-palm"); they are manifested in the simplification (skipping one of the links of the program); as well as in repetition of one of the elements as many times as the links contain the original sample of the motor program, and in adding additional program elements.

After completing a rehabilitative training program by young patients who had an ischemic stroke, the reevaluation of motor function scores was conducted. As a result of a comparative evaluation of the motor function scores at the voluntary level in young patients who had ischemic stroke – with due consideration to the hemispheric localization of the impact site and the lateralization profile before and after the rehabilitative training program – statistically significant differences in the groups of subjects (Table 2) were revealed.

Indices		Right-handed Patients		Left-handed patients	
		Damage of leading (left) hemisphere	Damage of non-leading (right) hemisphere	Damage of leading (left) hemisphere	Damage of non-leading (right) hemisphere
Voluntary level движений	Kinesthetic praxis	0,024*	0,033*	0,027*	0,029*
	Kinesthetic praxis	0,031*	0,011*	0,010*	0,017*
	Spatial praxis	0,022*	0,021*	0,029*	0,034*
	Dynamic praxis	0,028*	0,037*	0,022*	0,024*
	The completion of specified sequence of movements	0,022*	0,034*	0,016*	0,021*
	Independent formation and execution of the serial organization of movements that make up the motor (manual) program	0,019*	0,030*	0,012*	0,029*

* – the statistical significance of differences

Table 2. The results of the significance of the differences in motor function indices in young patients who had an ischemic stroke before and after rehabilitative training (Friedman $\chi 2$, $p<0,05$)

At the voluntary level of movement construction in young patients with ischemic stroke – regardless of the hemispheric location of the impact site and the lateralization profile – the restoration of both the execution of a given sequence of movements (serial organization of movements according to the sample) and the independent formation and execution of serial organization of movements which constitutes a motor (manual) program of actions was discovered.

4 Summary

Thus, as a result of a preliminary assessment of locomotor and voluntary levels of movement construction in young patients who had an ischemic stroke – irrespective of the hemispheric location of the impact site and the lateralization profile – malfunctions of the motor functions were discovered. At the same time, it was clearly found that – depending on the hemispheric localization of the impact site (in the leading or non-leading hemisphere) and on patient's lateralization profile – the depth of malfunctions vary as well as their qualitative manifestations. The revealed specific manifestations of motor function disorders in young patients who had an ischemic stroke were taken into account when organizing the content of the rehabilitative training program.

As a result of the reassessment of the indicators of locomotor and voluntary levels of movement construction, it was discovered that: the most intensive dynamics in the rehabilitative training of young patients with ischemic stroke was detected in left-handed patients with localization of impact site. The minimal effect of rehabilitation of serial organization of movements is noted in right-handed patients of young age who had an ischemic stroke with localization of the impact site in the leading (left) hemisphere.

5 Conclusions

The practical relevance of the empirical results is following: after completing the program of rehabilitative education by young patients who had ischemic stroke, regardless of the hemispheric location of the impact site and the lateralization profile, it was reliably confirmed that serial organization of motor skills, which forms the basis for the formation of self-service skills, was successfully recovered.

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