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The Recovery of Complicated Upper Limbs Movement Functions of Poststroke Patients

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Abstract: In chronic stage of stroke, it is necessary to pay attention to the complex spatial movements training along with the traditional restoration of balance, strength of particular muscles, and paretic limb joints mobility. The aim of the study was to evaluate the effectiveness of robotic therapy in the recovery of upper limb function in the chronic stage of stroke. The study involved 52 patients with ischemic stroke in the middle cerebral artery. The patients were divided randomly into 2 groups. All patients (5 days/wk × 3 wk) got gymnastics by the standard technique, massage, laser, and pulsed currents therapy. Main group patients (n = 36) extra received complex spatial movements, speed, fluidity, precision and agility training by the robotic electromechanical device Multi Joint System (MJS) (40 minutes, 5 days/wk × 3 wk). Analysis of the results of the study showed a statistically significant difference in improving ROM of the elbow and shoulder joints, speed and accuracy of movement in the main group compared with the control. Hardware recovery of complex spatial upper limb movements in the chronic stage of stroke increases the functionality and independence of the patient's domestic skills.

Key words: Stroke, rehabilitation, upper limb, shoulder joint, robotic therapy, electromechanical device.

1. Introduction

The majority of scientific researchers are devoted to using of robotic technology for rehabilitation of patients suffering from upper limb poststroke paresis. [1-9]. Currently all these electromechanical apparatus which are used for recovery of upper limb function have feedback block which receives the signals from proprio-, vision-, audio- and touch- receptors for quality control of the movement during the process of training and creates favorable condition for motor response and reorganization [9, 10]. Bernshtein [11] attached great importance to psychophysical characteristics of movement like spatial coordination (dexterity), accuracy, speed and smoothness, along with muscle power, tone, and pain syndrome.

Nowadays the influence of spatial movements training on upper limb functional activity of poststroke patients is thoroughly studied [9, 10, 12-15]. According to Hsui-Yun [9] and Wu [10] the motor reeducation with feedback training of dexterity of movement significantly improves the upper limb motor function after stroke. However, these trainings are underestimated. According to Masa [14], smoothness is the main characteristics of physiological and healthy upper limb movement. The authors revealed that robotic training focusing on smoothness and accuracy in poststroke patients have better rehabilitation prognosis with less patient's effort. Blanc [12] considers that robotic therapy is the main condition for patient readaptation. As a result of functional apparatus feedback task-specific trainings a patient adapts to everyday life (having meals, toilet, self-care, and professional skills) [4, 16-21]. What is more, virtual and game trainings activate cognitive and emotional processes in the brain, thereby supporting constantan attention during the exercise and high motivation during all course of treatment in patient [5, 8, 14, 22-24].

Up to the present there is no common opinion on

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the effectiveness of robotic therapy for recovery of poststroke upper limb function in comparison with traditional therapy [4, 14, 19, 25, 26]. Klamroth-Marganska [19] found out significant increase of upper limb activity of poststroke patients after the courses of traditional and robotic therapies without essential statistics differences. Lo et al. [25] discovered the high effectiveness of movement disorders recovery after robotic therapy which was compared with effectiveness of high intensive traditional therapy. They also admitted the absence of noticeable functional changes after non-intensive traditional therapy. On the contrary, Laver [4] in their review proved the advantages of the robotic therapy in the treatment of hand functional activity and the lack of vital differences in the recovery of muscle strength and spasticity of upper limb. Masa et al. [14] and Milot et al. [26] didn't notice essential statistic differences between robotic and traditional therapies according to functional activity scale.

Therefore, the analyses of scientific literature demonstrate the widespread of robotic methodic in rehabilitation upper limb function after stroke. However, the advantages of robotic technology haven't been studied enough.

The aim of research is to define the effectiveness of robotic therapy in recovery of upper limb function in the chronic stage of stroke. The tasks of research are as follows: (1) To estimate the dynamics of neurological status and pain syndrome under the influence of robotic therapy; (2) To investigate the biomechanical changes in the upper limb (strength, range of motion, accuracy performing the exercises); (3) To find out the main effect of robotic feedback training of upper-limb function in poststroke patients.

2. Material and Methods

We examined 52 poststroke patients (28 men, 24 women), aged 59 ± 12. The timing from the onset of stroke was from 9 to 55 months (in average 32 months). 34 patients had right middle cerebral arteria stroke, 18-left middle cerebral arteria stroke. All patients were examined on the first and the last days of research. We estimated neurological status, spasticity level by Ashworth scale (shworth, 1964); muscle strength by Weiss scale (Peak, 1996; Weiss, 1986). 25 participants noted pain syndrome in upper limbs on the affected side, it was estimated by VAS scale (Huskisson, 1974). The ROM (range of motions) in the joints was estimated by goniometry. During the research we defined active flexion, abduction, external rotation in the shoulder joint, flexion and extension in the elbow joint, flexion and extension wrist joint. Functional activity of upper limb was estimated by Fugl-Meyer scale (Fugl-Meyer, 1975). The point D of Fugl-Meyer scale was measured separately and these data were used to determine speed and accuracy of upper limb. Clinical-functional characteristics of participants are introduced in Table 1.

Including criteria were: Ischemic stroke in the middle cerebral artery, chronic period of stroke, muscle strength not less than 2 points by Weiss scale,

Table 1 Clinical-functional characteristics of participants.

Parameters	(n = 52)	Main group (n = 36)	Control group (n = 16)
Age	59 ± 12	52 ± 6	58 ± 4
Sex (m/f)	28/24	18/18	10/6
Side (r/l)	34/18	22/14	12/4
Time, months	32 ± 23	28 ± 12	33 ± 15
Weiss scale, points	3.5 ± 0.9	3.3 ± 0.8	3.8 ± 0.7
Ashworth scale, points	1.7 ± 0.8	1.9 ± 0.7	1.6 ± 0.8
VAS scale, points	3.5 ± 0.9	5 ± 0.9	2.5 ± 0.9
Fugle-Meyer scale, points	95 ± 21	91 ± 15	97 ± 16
Fugle-Meyer, point D, points	3.7 ± 1.4	3.5 ± 1.2	3.7 ± 1.2

spasticity not more than 3 points by Ashworth scale, level of pain syndrome not more than 6 points by VAS; ROM: more than 15° active flexion in the shoulder joint, more than 15° flexion in the elbow. Excluding criteria were: trauma and operation in the shoulder in anamnesis, moderate and severe cognitive and speech disorders, which do not let the patients to perform the exercise correctly during the training.

All patients were randomized into 2 groups. There were 36 patients in the main group and there were 16 in the control group. The patients of the main and control groups were comparable by sex, age, clinical outcomes, period of stroke. All patients got the treatment consisted of physical therapy, massage of upper limb and collar zone, laser therapy and low frequency electrostimulation of the shoulder muscles. Additionally, the patients of the main group got the course of robotic therapy for affected upper limb by Multi-Joint System (MJS, Ita) in active-passive mode of training. The constructive features of MJS allow carrying out constant control of scapula to provide the motions in 3 spaces of the shoulder joint with smooth transition from one to another; to model any directions of the movement with feedback control. The patients of the control group did not get the robotic treatment. All procedures were performed for 5 days a week, during 3 weeks. The average time of MJS training was 40 min.

The training protocol included the exercises for extension ROM in all 3 spaces of shoulder joint, game and graphic sport-tasks (tennis) and task-specific exercises (light, cleaning the kitchen, wiping of table, hanging up clothes, shifting items, combing, eating, upper movement during the walk). We especially input the exercises for training difficult spatial movement (accuracy, speed, smoothness). Implementation of the tasks provided with active and active-passive movements of paresis upper limb with ortesis of apparatus. All tasks were provided under patient visual self-control and therapist audio control.

Statistical analysis. Statistical analysis of data was done with SPSS 16.0. We used test of Kolmagorov-Smirnov to determine the type of selection distribution. We used independent-sample T test, paired-sample T test, ANOVA analyze to estimate reliability statistical differences for normal selection distribution. We used Mann–Whitney U test, Wilcinson’s, Kruskal–Wallis H test, chi-squared test to estimate reliability statistical differences for abnormal selection distribution.

Moreover, we used dynamics of clinical-functional indicators which is difference in points [Δ] between patient’s condition before and right after treatment for each analyzed parameters. For assessment of rehabilitation efforts effectiveness was provided the comparative analysis Δ for all clinical groups of the patients.

3. Results

The Table 2 is shown the dynamic (the difference between patient’s condition before and after treatment) of estimated clinical parameters. The clinical analysis after robotic treatment shows significant difference in two groups muscle strength, muscle tone, ROM in shoulder, elbow and wrist, functional activity of upper limb ($p < 0.05$). In main group dynamic of muscle strength by Weiss scale was 6.1%, in control group—2.6% ($p = 0.001$). Dynamic of muscle tone by Ashworth scale: main group—10.5%, control group—6.2% ($p = 0.009$). Dynamic of ROM: ROM shoulder flexion: main group—26.6%, control group—10.8% ($p < 0.001$); ROM shoulder extension: main group—28.3%, control group—12.4% ($p = 0.001$); ROM shoulder external rotation: main group—43,5%, control group—6.4% ($p < 0.001$); ROM elbow flexion: main group—12.3%, control group—2.1% ($p = 0.001$); ROM elbow extension: main group—63,7%, control group—18.5% ($p = 0.02$); ROM wrist flexion: main group—32.7%, control group—8.0% ($p = 0.001$); ROM wrist extension: main group—21.7%, control group—4.2% ($p < 0.001$). Follow in Fugl-Mayer scale dynamics of functional

Table 2 The dynamics of clinical-functional indicators of the main and control groups after treatment.

Parameters	Main group (n = 36)	Control group (n = 16)	Reliability (p)
Weiss scale, points	0.2 ± 0.1	0.1 ± 0.1	$p = 0.001$
Ashworth scale, points	0.2 ± 0.2	0.1 ± 0.1	$p = 0.009$
ROM flexion shoulder, degrees	29 ± 17	12 ± 10	$p < 0.001$
ROM abduction, degrees	31 ± 19	14 ± 7	$p = 0.001$
ROM external rotation, degrees	16 ± 9	3 ± 5	$p < 0.001$
ROM flexion elbow, degrees	16 ± 14	3 ± 5	$p = 0.001$
ROM extension elbow, degrees	10 ± 14	2 ± 4	$p = 0.02$
ROM flexion wrist, degrees	15 ± 12	4 ± 6	$p = 0.001$
ROM extension wrist, degrees	9 ± 9	2 ± 4	$p < 0.005$
Fugle-Meyer scale, points	5 ± 4	2 ± 1	$p = 0.009$
Fugle-Meyer, point D, points	0.5 ± 0.5	0.1 ± 0.2	$p < 0.001$
VAS scale, points	(n = 18) 2.8 ± 1.9	(n = 7) 1.3 ± 0.8	$p = 0.001$

activity of upper limb was in main group—5.5%, control group—2.1% ($p = 0.009$). Dynamics of speed and accuracy of movement by point D Fugl-Meyer scale in main group was in about 5.5 times higher than control group (14.3% and 2.7%, respectively, $p < 0.001$). Dynamic of pain level by VAS scale were similar but was significant (main group—56%, control group—52%, $p = 0.001$).

4. Discussion

Our research demonstrates the significant improvement of all estimated functional upper-limb signs of poststroke patients after robotic therapy in comparison with traditional therapy.

There are a lot of articles which we observed with the similar results in dynamic of recovery of speed, smoothness, and accuracy of movement [8, 10, 14, 15, 25-32]. Milot et al. [14] emphasized that simultaneous increase of speed, smoothness, improvement in shoulder abduction and elbow flexion are the main factors in the recovery of upper limb function. Our research reveals the enlargement of ROM in shoulder and elbow joints in 5 times in the main group in comparison to the group of traditional therapy. In our research, we also note the increase of speed of motion in the main group. All of it caused the results in improving of upper limb functional activity after treatment according to Fugle-Meyer scale.

Our observation demonstrates the insignificant influence of conventional therapy on speed and accuracy of movement. Our data agrees with the results of Grabher [29], who revealed the increasing of accuracy in affected upper limb after robotic therapy and the absence of dynamic after traditional therapy without feedback technology.

Masa [14] also noted effectiveness of robotic therapy in rehabilitation of upper limb functional activity of patients with mild and moderate paresis without any significant differences of patients with severe paresis. The peculiarity of our research is the investigation of influence of robotic technology on patients with mild and moderate movement impairment of upper limb in complex rehabilitation in chronic stroke patients.

5. Conclusions

Therefore, our research shows the effectiveness of using robotic therapy for recovery biomechanical indicators and functional condition of upper limb for patients with mild and moderate motor impairment in chronic period of ischemic stroke. Applying robotic devices creates condition for training of complicated functional patterns and psychophysical characteristics of movement in friendly environment what conventional therapy can’t do. Complex treatment by robotic with conventional therapies contributes the

acceleration recovery of upper limb impairments and improves rehabilitation prognosis.

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