The Role of Robotic Mechanotherapy in the Recovery of Mobility in Patients after an Acute Cerebrovascular Accident

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Abstract

Hemiparesis of various severity is a common type of motor disorder resulting from an experience of a stroke. It is motor disorders that lead to the disruption of such categories of activity as the ability to move and self-care, which entails a limited patient mobility. The study has included 35 patients with motor disorders resulting from acute cerebrovascular accidents (CA), and the patients have undergone medical rehabilitation.

Clinical research method (Ashworth and Rivermead scales) and mathematical statistics have helped assess the positive effects of robotic mechanotherapy, which was used in the rehabilitation of stroke patients.

As a result of rehabilitation measures with the use of robotic mechanotherapy, 68.2% of the examined subjects have developed significant strength in the hand, and 45.5% - in the leg ($p<0.005$). In the remaining subjects, no significant improvement in the motor function has been observed, although mobility has improved in all examined patients and the average Rivermead mobility index has been 11.4±2.1 out of 15 ($p<0.001$).

Keywords: *Acute cerebrovascular accident, stroke, paresis, validated scales, Ashworth scale, Rivermead Mobility Index, robotic mechanotherapy, Armeo Power device, Lokomat device.*

Introduction

Although the issue is very evident, as is the need in finding solutions, data provided by the World Health Organization (WHO) suggests that cerebrovascular disorders of various genesis are still a leading mortality and disablement factor. It should be noted that a number of international authors (Sarti C., Rastenyte D., Cepaitis Z., et al., 2000; Howard G., Howard VJ., Katholi C., et al., 2001; National Center for Health Statistics. Health, United States, 2005: With Chartbook on Trends in the Health of Americans[1]. Hyattsville, 2005; Claire L. Allen, 2008; Shinichiro Uchiyama, Noriaki Nakaya, Kyoichi Mizuno, 2009; Benamer H.TS., Grosset D., 2009) consider the stroke issue a global epidemic, which claims lives and threatens the world. The annual 0.2% (2000 new cases per 1,000,000 of people) increase in stroke incidence, as well as the growing mortality during each following year (4,400,000 deaths), high disability rate, low complete recovery rate, impact nations' socioeconomic indicators[2].

According to statistics, in 2017, cardiovascular disorders were the number one cause of death (59.7%), and the most common causes of these were ischemic heart disease, arterial hypertension and their complications (myocardial infarction, cerebrovascular accidents, etc.) Men aged 30 to 59 are three times more likely to die of infarction and twice more likely to die of a stroke than women[3]. According to some authors, the incidence of strokes in Uzbekistan ranges between 0.9 and 1.4 cases per 1000 people, while mortality in the acute period can reach 35 to 40% (Asadullaev M.M. et al, 2002; Akhmedov O.T. et al., 2002; Gaphurov B.G., Alikulov A.N., 2000)[4].

According to published data, in Belarus the total number of disabilities resulting from cerebrovascular accidents is 6500, and only 10% to 15% of patients get back to work[5].

It is important to provide proper diagnostic of the state of the motor function with a mandatory quantitative assessment of the severity of dysfunctions and disabilities, which can be completed with the help of validated scales and tests[6].

It is motor functions that disrupt such abilities as movement and self-care and limit patients' movement[7].

Recovery of mobility is a paramount goal of the complex rehabilitation system. In medical rehabilitation, the choice of recovery tactics implies an early start, use of individual approaches and integrated method, which, in turn, can help improve patients' mobility[8]. Normalization of pathologically impaired functions is associated with broad incorporation of robotic mechanotherapy into the recovery process. Regaining joint movement with the use of specially designed devices does provide for optimal physical activity even in the most severe cases, when a patient is unable to move independently[9]. An advanced robotic device uses computer programs that regulate workload on an individual basis[10]. A specific thing about the tactics is proportionate exercise load, abduction, adduction, flexion, extension, and rotation [12].

The goal of the study is to evaluate the efficacy of robotic mechanotherapy in the treatment of mobility dysfunctions as part of a rehabilitation program for apoplectic patients.

Materials and Research Method

The study has involved 35 patients with stroke-related motor dysfunction, who underwent medical rehabilitation in the Republican Clinical Hospital of Medical Rehabilitation (the Republic of Belarus, Minsk District).

A group of 23 subjects (66%) have had ischemic CA, 12 subjects (34%) have had hemorrhagic CA. The patients were hospitalized on the 11th to 15th day from the beginning of the condition. All subjects have undergone a rehabilitation program, which includes medicinal therapy, walking training, coordination and equilibrium exercises, physiotherapy (electric stimulation, magnetic and laser therapy, heat therapy, cryo-therapy, massage), and social rehabilitation.

The treatment group (Group 1) has consisted of 20 subjects, including 9 female subjects (45%) and 11 male subjects (55%). Median age has been 56.6±9.6 (Table 1). Apart from the general exercises, robotic mechanotherapy exercises were added to the treatment group's program.

The control group (Group 2) has consisted of 15 patients (8 men and 7 women) aged 53.8±7.8 with similar demographic characteristics, type of stroke and severity of neurologic impairment, and their rehabilitation program has not included robotic mechanotherapy.

Table 1: Sex and age Distribution

Group	Number of subjects			Median age
	Male	Female	Total	
Treatment	11	9	20	56,6±9,6
Control	8	7	15	53,8±7,8
Total	**19**	**16**	**35**	**55,2±8,7**

The Department of Medical Rehabilitation has developed an individual medical rehabilitation program for both treatment and control group based on clinical symptoms and specifics of the main disorder, age and underlying pathologies.

Robotic monotherapy has been carried out with the use of devices intended for functional upper limb therapy (Armeo Power) and lower limb (Lokomat) therapy, manufactured by Hocoma AG, Switzerland. In the groups, the treatment has lasted for 21 to 28 days. Robotic mechanotherapy has been carried out on a daily basis before the afternoon, sessions have lasted 30 to 40 minutes. The procedure has been applied to the lower and upper limbs at a time with an interval of 15 to 20 minutes.

To recover the function of the affected upper limb, an Armeo Power training device has been used for bilateral forearm pronation/supination and wrist flexion/extension[13]. The training has included exercise for the upper limbs with affected elbow and shoulder joints, which uses the biofeedback principle with the involvement of the wrist's prehensile function and compensation of the forearm's and shoulder's weight[10]. The training would start with minimal possible workload and amplitude of movements with a gradual increase in the intensity and complexity of exercises[12]. For the lower limbs, the Lokomat system has been used, as it consists of robotic walking orthoses, a body mass support system and a running machine [14]. The training would start from a 100% body-weight unloading with a full and complete control of the walking pattern by the Lokomat device.

The training has implied a gradual lowering of the body-weight unloading along with increasing exercise duration, walking speed, hip elevation, and development of an independent walking function. During a session, a patient is suspended on a belt harness. It is possible to adjust the load on the lower limbs depending on the patient's ability to stand, and enables patients to walk with or without assistance. At the early stage, the robot assists in making passive movements with the lower limbs and, as the patient 's motor function recovers, the amount of active movement increases.

Clinical research method (with the use of a modified Ashworth spasticity scale to determine the intensity of paresis and evaluate muscle strength, the Rivermead Mobility Index to evaluate mobility) have been used to evaluate the subjects' neurological status, and they have served as criteria of efficacy of the rehabilitation procedures. The newly obtained results have undergone statistical processing with the use of the applied Statistica 7.0 package (StatSoft Inc., the USA), and the Student's t-test.

The Ashworth Scale has been used to evaluate muscular resistance while performing passive joint movements. The starting position is lying face up, fully relaxed – for measurement of elbow and knee flexion and extension. Next, five consecutive passive elbow and knee joint movements are made over a length of time needed to pronounce the figure 1969 (nine hundred sixty-nine). The exercise helps evaluate the average muscle tone change index. The movement should be made within the range/until pain.

The muscle tone test parameters are:

0 = No increase in muscle tone;

1 = a slight increase minimal tension at the ends of the flexion/extension range of motion;

2 = a slight increase with minimal muscular resistance (tension) less than halfway into the whole range of motion;

3 = a moderate increase throughout the range of motion with no resistance to passive movements;

4 = a significant increase with high resistance to passive movements;

5 = rigid flexion/extension (flexion/extension contracture).

The Rivermead Mobility Index (RMI) is one of the simplest and easiest-to-perform measures of not only a patient's walking, but general mobility as well. The RMI value is the number of points assigned by a question, based on which a physician can answer positively. The RMI value can range from 0 (unable to make any voluntary movements without assistance) to 15 (capable of running a distance of 10 m). The test is usually done for 10 minutes.

To evaluate mobility, different parameters have been used, such as rolling over in bed, moving from lying to sitting, maintaining balance in the sitting position, moving from sitting to standing, standing without support, moving and walking around a room with (if necessary) or without support tools, walking upstairs, walking outside one's living space (on even surfaces), walking around a room without using support tools, picking up objects (see Table 2).

Table 2: RMI criteria

№	Activity	Question
0	Immobile	What kind of movements does a patient make during a day?
1	Rolling over in bed	Can you roll from back to side without help?
2	Moving from lying to sitting	Can you move from lying to sitting on the edge of your bed?
3	Maintaining balance in the sitting position	Can you sit on the edge of your bed without support for 10 seconds?

№	Activity	Question
4	Moving from sitting to standing	Can you get up (from various types of chairs) over less than 15 seconds and stand for 15 seconds (holding on to something with your hands or, if necessary, using a support tool)?
5	Standing without support	Monitoring a patient standing for 10 seconds without support.
6	Moving	Can you get up from your bed and sit down on a chair without assistance?
7	Walking around a room with support (if necessary)	Can you walk 10 m using support tools, but without using someone else's help?
8	Walking upstairs	Can you climb up a stair flight without help?
9	Walking outside one's living space (on even surfaces)	Can you walk outside your home on a sidewalk without help?
10	Walking around a room without using support tools	Can you walk 10 m around your apartment without using a crutch, orthosis or someone else's help?
11	Picking up objects	If you have spilled an object, can you walk 5 m, pick it up and get back?
12	Walking outside one's living space (on uneven surfaces)	Can you walk outside your house without someone else's help on uneven surfaces (grass, gravel, snowdrifts, etc.)?
13	Taking a bath	Can you get into and out of your bathroom (shower room) without supervision and take a bath/shower alone?
14	Walking four steps up and down	Can you walk four steps up and down without holding onto the railing, but using support tools?
15	Running	Can you run 10 m without limping over 4 seconds (brisk walking is allowed)?

Results and Discussion

Before the rehabilitation procedures started, the majority of subjects had moderate and severe mobility deficits. For instance, according to the Modified Ashworth Spasticity scale, in the treatment group (n=20), 31.8% of subjects had moderate or severe hand paresis; 27.3% of the subjects had very severe hand paresis, 9.1% had mild hand paresis. More than half of the group (59.1%) had severe leg paresis, 31.8% had moderate leg paresis, 9.1% were dealing with mild cases. In the control group (n=15), 28.7% of the subjects had moderate hand paresis, 33.4% - severe had paresis, 29.4% - very severe hand paresis; 98.5% of the subjects had mild hand paresis, more than half of the group (62.3%) had severe leg paresis, 29.6% - moderate leg paresis, and 8.1% of the subjects had mild leg paresis (Table 3).

Thanks to the rehabilitation procedures, which have involved robotic mechanotherapy, 68.2% of subjects have gained hand strength (p<00.5), 45.5% of the treatment group subjects have gained leg strength; likewise, the control group subjects have shown a 52.7% increase in the hand strength, and 38.6% - in the leg strength (see Table 4).

Table 3: Clinical characteristics of subjects with mobility deficits

Affected area	Type of paresis	Treatment group	Control group
		Incidence (%)	
Hand paresis	Very severe	27.3	29.4
	Severe	31.8	33.4
	Moderate	31.8	28.7
	Mild	9.1	8.5
Leg paresis	Severe	59.1	62.3
	Moderate	31.8	29.6
	Mild	9.1	8.1

Table 4: Follow-up muscular strength and spasticity dynamics according to the Ashworth scale in the treatment and control groups.

Affected area	Treatment group		Control group	
	Points			
	Before treatment	After treatment	Before treatment	After treatment
Hand paresis	3.65±1.01	2.95±1.16*	3.93±0.92	3.4±1.08
Leg paresis	3.4±0.73	2.95±1.07*	3.46±0.72	3.07±0.93

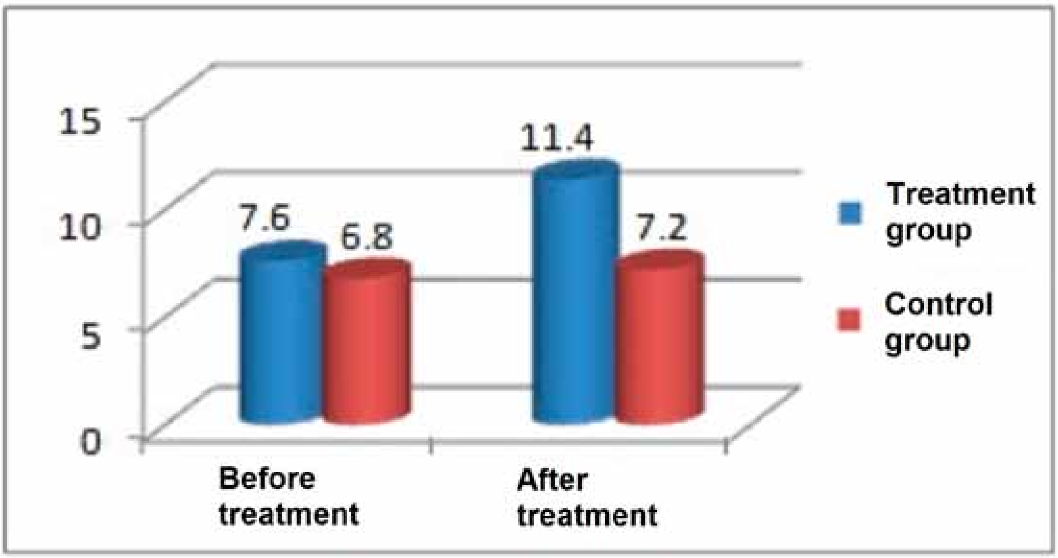

Figure 1: Post-rehabilitation mobility dynamics

The average admission RMI value was 7.6±3.5 in Group 1 and 6.8±3.7 in Group 2 out of 15.

After the rehabilitation procedures, all subjects showed a better mobility, and the improvement was more pronounced in the treatment group: the Rivermead Mobility Index averaged 11.4±2.1 in the treatment group and 7.2±3.2 in the control group out of 15 ($p<0.001$) (Fig.1.). This has been achieved through patients' adaptation to a mobility impairment and development of compensatory and substitutive functions.

The locomotion training with partial body weight unloading with the use of a suspension harness enables free hand movement and more natural walking movement pattern. These devices feature motors, which provide for continuous symmetrical and timeless training sessions.

The dynamics shows a significant spasticity decrease in the treatment group, where subjects have undergone robotic mechanotherapy. A continuous sensor feedback from extensor load receptors, which is observed during this type of walking and hand movement, help to stimulate neuronal networks, which activate muscle locomotion activity patterns and provide for neural plasticity.

The integrated therapy with the use of robots has helped speed up the patients' walking, improved biochemical walking characteristics, reduced muscle tone in the upper and lower limbs in the group of subjects under control dealing with post-stroke hemiparesis during rehabilitation.

Conclusion

The research has made it possible to conclude that the program, which has included robotic mechanotherapy, has been more effective, as it is seen from the higher Ashworth muscle strength indexes in affected limbs, increased Modified Rivermead Mobility Indexes, as well as more a pronounced improvement of impaired functions. Subjects, who have not gone for additional training, have shown minimal improvement according to these characteristics.

Ethical Clearance: No ethical approval is needed.

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Conflict of Interest: Nil

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