КЛИНИЧКИ ИСТРАЖУВАЊА

ЕФЕКТИТЕ ОД АПЛИКАЦИЈА НА РАДИЈАЛНА ЕКСТРАКОРПОРАЛНА ТЕРАПИЈА СО УДАРНИ БРАНОВИ НА СПАСТИЧНА ШАКА ПО МОЗОЧЕН УДАР

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Извадок

Спастицитетот на шаката по мозочен удар ги зголемува тешкотиите на болните во секојдневното самозгрижување и ја ограничува ефикасноста на рехабилитацијата. Радијалната екстракорпорална терапија со ударни бранови (РЕКТУБ) е предложена како алтернативен третман за редукција на спастицитетот. Целта на истражувањето беше да се евалуираат ефектите од апликација на РЕКТУБ на спастична шака по мозочен удар. Материјал и методи: Контролирана клиничка студија во која беа вклучени 30 пациенти со спастична шака по мозочен удар, поделени во две групи. Испитуваната група беше третирана со РЕКТУБ (6 третмани секој втор или трет ден) и стандардна рехабилитациона програма. Контролната група беше третирана само со стандарднарехабилитациона програма. За клиничка евалуација беа користени Модифицираната Ашфорт Сакала (МАС) и супскорот за моторно закрепнување од Фугл-Мајер тестот за процена на сензомоторната функција на горен екстремитет и тоа пред третманот, по завршување на 2-та, 6-та и 14-та недела од почетокот на рехабилитацијата. Резултати: Средната вредност на оценатa на МАС беше значително намалена кај испитуваната група веднаш по РЕКТУБ. Кај испитуваната група се забележа значително подобрување на скорот за моторно закрепнување на Фугл-Мајертестот. Овие резултати се задржаа 12 недели по третманот. Заклучок: РЕКТУБ го намали спастицитетот на шаката по мозочен удар и доведе до нејзино подобро моторно закрепнување.

CLINICAL SCIENCE

EFFECTS OF RADIAL EXTRACORPOREAL SHOCK WAVE THERAPY ON POST-STROKE HAND SPASTICITY

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Abstract

Hand spasticity after stroke increases the difficulties of daily living activities and limits the effectiveness of rehabilitation. Radial extracorporeal shock wave therapy (RESWT) has been suggested as an alternative treatment in spasticity reduction.The aim of the study was to evaluate the effectiveness of RESWT on hand spasticity in stroke patients. Material and methods: Controlled clinical trial in which 30patients with post-stroke hand spasticity were assigned in two groups. The examined group received RESWT (6 treatments in a period of two to three days) along with a standard rehabilitation programme. The control group received only standard rehabilitation programme. Clinical evaluations for both groups were performed using the Modified Ashworth Scale (MAS) and the subscore for motor recovery of the Fugl–Meyer assessment for the upper extremity at baseline, immediately after the second, at 6th and 14th week from the start of the rehabilitation.Results: The mean MAS score was significantly decreased inthe examined group after the RESWT.The examined group showed a significant improvement according to Fugl-Meyer test score after treatment. These results lasted 12 weeks after the treatment. Conclusion: RESWT has reduced the hand spasticity and led to a better motor outcome of spastic hand after a stroke.

Introduction

Spasticity after a stroke has a neural component ("a motor disorder characterized by the velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, which results from hyperexcitability of the stretch reflex, as one component of the upper motor neuron syndrome disorder"- Lance, 1980) and a biomechanical component (an increase in the number of myosin bridges between the myofilaments - shortening and contractures of the myocytes - Carey and Burghardt, 1993).[1-4]

Within the first 6 weeks after the stroke, the prevalence of spasticity is within the range from 4% to 27%. The spasticity rate was 19% three months after the stroke, it was from 21.7% to 42.6% at six months, and 17% to 38% after a period of 12 months from the stroke. Spastic upper extremity was observed in 43% of patients with ischemic stroke consequences. In 19%, it was affected by a severe degree of spasticity (with grade 3 according to the Modified Ashworth Scale) compared to 5-6% of the lower extremity.[2-5] The pathophysiology of spasticity is very complex and still not completely understood. Increased muscle tone and tendon reflexes are a result of changes in the equilibrium of input impulses from the cortico-reticulo-spinal and other descending tracts of the motor and interneuron circuits in the spinal cord, and absence of an intact corticospinal system.1,5 The resistance to passive stretching of the muscle is not always accompanied by an increased stretching reflex, but it is also due to changes in the biomechanical properties of the muscle. This is also supported by the electromyographic clinical studies which prove that increased muscle tone caused by an increased reflex activity reaches its maximum within a period of 1 to 3 months following the stroke. After 3 months, the possible increase in resistance to passive stretching is due to intrinsic changes in the muscles. In patients with spasticity, the affected muscles are subjected to adaptation, which includes formation of a higher percentage of connecting bridges (myosin bridges –except for those that are separated from the actin filaments during a relaxed muscle state) between the myofilaments. These rheological changes in the muscles lead to shortening and possible contractures of the myocytes and shortening of the tendons.[6-8]This is an important concept, mostly because the approaches to treatment of the two "types" of hypertonia are different. An increased "neural" tone can respond to antispasticity medications or injections of botulinum toxin or phenol while a"biomechanical" tone will not respond to the abovementioned. It is best treated with rehabilitation procedures and physical modalities.

A spastic upper extremity after a stroke causes difficulties in everyday life, therefore it results in hindered feeding, maintaining hygiene, turning in bed, writing, driving a wheelchair. All of these problems slowly but surely lead to reduced independence and a need to engage another person who will assist the patient with his/her everyday activities. If left untreated, it is accompanied by complications such as reduced range of movements, reduced postural control, presence of painful spasms and contractures, which additionally complicates the condition. Hence, the reduction of spasticity in many cases will contribute to an improved residual arm function.

Radial extracorporeal shock wave therapy (RESWT) involves an application of high-intensity acoustic radiation (high-energy acoustic waves-shock waves). Shock waves are defined as the sequence of single sound pulses which are characterized by high point of pressure that can reach up to 100 MPa (1000 Bar), fast reach of this pressure within a short period (less than 10 ns), short duration (10 μs), followed by a variable negative pressure that can affect cavitation and a frequency of 16-20 Hz.[9-12]

Over time, it was proven that RESWT is an efficient and non-invasive method for the treatment of localized musculoskeletal pathology including epicondylitis, calcar calcanei, plantar fasciitis, disorders of the rotator cuff, treatment of trigger points, chronic tendinopathy, pseudoarthrosis, etc.[13-17]

Recently, attempts have been made to extend the therapeutic range of RESWT, thus proving its effectiveness in reducing spasticity.[18-31]

The aim of this study was to evaluate the

effects of RESWT in the treatment of post-stroke hand spasticity as well as its possible efficacy in motor recovery.

Material and methods

This controlled clinical trial was conducted in 2018, at the Institute for Physical Medicine and Rehabilitation in Skopje, Republic of Macedonia. A total of 30 patients with post-stroke hand spasticity, who were receiving an outpatient or stationary rehabilitation treatment, were included. All participants were fully informed about the trial, and each of them signed an informed consent form on voluntary participation. The study was approved by the Ethics Committee of the Medical Faculty, Ss. Cyril and Methodius University in Skopje.

The inclusion criteria were as follows: a) age ≥18 and ≤80 years; b) minimum of 3 months since an ischemic or ahaemorrhagic stroke; c) hand and fingers spasticity of the affected limb; d) at least 3 months of unchanged dosage of antispasticity medications or GABA-ergic medications if the patient received such; and e) at least 3 months of possible use of a passive forearm orthosis. The criteria for exclusion from the study were: a) not belonging to the age group of interest; b) use of anticoagulant therapy; c) previous or planned treatment with botulinum toxin, phenol, alcohol or surgical treatment; d) contracture in the hand and fingers of the affected limb; and e) Sudeck syndrome/local inflammation at the area of application of the treatment.

The participants in the examined group (EG) were treated with RESWT and a standard rehabilitation programme for patients with hemiplegia/hemiparesis after a stroke, while those in the control group (CG) were treated only with a standard rehabilitation programme. The period of rehabilitation in both groups lasted 4 weeks.

RESWT treatment: The application of RESWT was conducted with the device BTL-5000 SWT Power Appliance (BTL Industries Ltd., United Kingdom). A total of 6 (six) treatments were applied every two or three days over the spastic muscles according to the manufacturer's recommendations: 1.500 shocks over m.flexor carpi radialis and m.flexor carpi ulnaris and 3.500 shocks on the muscles of the volar side of the hand. The applied energy was of 2Bars and a frequency of 10Hz. The application of the treatment started at the beginning of the rehabilitation.

The standard rehabilitation programme intended for patients with hemiparesis/ hemiplegia after a stroke consisted of kinesitherapy, manual massage and occupational therapy.

The overall process of rehabilitation of the patients from both groups lasted 4 working weeks from the start of the rehabilitation.

The assessment of the spasticity of the wrist and the fingers was performed with the Modified Ashworth Scale (MAS). For convenience of the statistical analysis, MAS grade 1+ was point 2; grades 2, 3, and 4 were respectively matched to 3, 4, and 5. For an assessment of the motor recovery of the hand, the subscore for motor recovery of the Fugl–Meyer assessment (FMA) for the upper extremity was used.

The clinical findings were evaluated at the same time points for the patients from both groups: before the start of the rehabilitation, immediately after the completion of the second, sixth and fourteenth week of the rehabilitation (i.e. for the examined group before the RESWT application, immediately after the completion of the RESWT application, immediately after the first and the third month upon completion of the RESWT application).

Results

The trial covered a total of 30 respondents, of which 23 (76.7%) had ischemic, and 7 (23.3%) had a haemorrhagic stroke. In the EG, 15 (50%) patients were treated with RESWTand a standard rehabilitation programme, while in the CG 15 (50%) patients were treated with a standard rehabilitation programme. Men and women were represented in EG as (53.3%) vs.7 (46.7%) and in CG as 6 (40%) vs. 9 (60%), with no significant association between gender and the group that the respondents belonged to (Pearson Chi-square=0.536, df=1, p=0.464). The average age of the patients in the examined group was 57.53±8.03 [95%CI (53.08-61.98)] with a minimum/ maximum age of 45/

69 years. In the control group, the average age was 60.47±13.67 [95%CI (52.89-68.04)] with a minimum/ maximum age of 19/ 69 years. There was no significant age difference between the groups (One Way ANOVA: F=0.513; p=0.480).

The average value of the MAS score both in EG and in CG was highest at baseline [3.9±1.1 IQR = 4 (3-5) vs. 3.4±0.9 IQR = 3 (3-4)], and lowest after 2 weeks of treatment [2.5±1.2 IQR = 3 (1-4) vs. 2.8±1.1 IQR = 2 (2-4)]. In each of the groups there was a significant difference between four measurement times related to MAS score values (Fridman test: Chi-Square (3)=39.833 p=0.00001) vs. Fridman test: Chi-Square (3)=21.514 p=0.00001) (Table 1). The Post Hoc Test analysis of the values of the MAS score, in accordance with the Bonferroni correction, in the EG suggested a significant difference between baseline/control1; baseline/control2 and baseline/control3 in favor of a significantly higher value at-baseline(Table 2). In the CG, a significant difference in the values of the MAS score was observed at baseline/control1; baseline/control2 and control1/control3 in favor of a significantly higher value at baseline vs.control3.

Table 1. Comparison of values of Modified Ashworth Scale score in the four measurement times by groups

Time of measurement	No. (N)	Average (Mean)	Std. Deviation	Min.	Max.	Percentiles		
						25th	50th (Median)	75th
Examined group - Friedman test: Chi-Square (3)=39,833 p=0,00001*								
Baseline	15	3.93	1.09	2	5	3	4	5
Control 1	15	2.47	1.25	1	4	1	3	4
Control 2	15	2.60	1.29	1	4	1	3	4
Control 3	15	2.87	1.19	10	4	2	3	4
Control group- Friedman test: Chi-Square (3)=21,514 p=0,00001*								
Baseline	15	3.40	0.92	2	5	3	3	4
Control 1	15	2.80	1.11	2	5	2	2	4
Control 2	15	3.00	1.19	2	5	2	2	4
Control 3	15	3.33	1.05	2	5	2	3	4

* significant for p<0.05

Table 2. Post Hoc Test of the values of Modified Ashworth Scale score by groups

Wilcoxon Signed Ranks Test	Baseline/ Control 1	Baseline/ Control 2	Baseline/ Control 3	Control 1/ Control 1	Control 1/ Control 2	Control 2/ Control 3
Examined group						
Z Asymp. Sig. (2-tailed)	(3.508) 0.000*	(3.542) 0.000*	(3.771) 0.000*	(1.414) 0.157	(2.449) 0.014	(2.000) 0.046
Control group						
Z Asymp. Sig. (2-tailed)	(3.162) 0.002*	(2.646) 0.008*	(1.414) 0.157	(1.732) 0.083	(2.828) 0.005*	(2.236) 0.025

* in accordance with the Bonferroni correctionsignificant for p<0.012

The comparison of the MAS score between groups in four measurement times did not indicate a significant difference (Table 3).

Table 3. Comparison of two groups according to the values of Modified Ashworth Scale score in four times

Mann-Whitney U test	Baseline	Control1	Control2	Control3
Z	(1.315)	(0.708)	(0.835)	(0.928)
Asymp. Sig. (2-tailed)	0.189	0.479	0.404	0.353

a. Group variable: examined / control* significant for p<0.05

The mean value of FMAin the EG was lowest at baseline 12.5±7.1 IQR=11 (7-15) and highest at 14 weeks of the treatment when it was14.2±7.3 IQR=12 (10-15). In the CG the value of FMA was lowest at baseline, and highest at 2 weeks of the treatment for 14.1±6.1 IQR = 15 (9-18) vs. 15.2±6.1 IQR = 15 (11-18). In each of the two groups, we found a significant difference between four measurement times related to FMA value [Fridman test: Chi-Square (3)=27 p=0.00001 vs. Fridman test: Chi-Square (3)=12.667 p=0.005] (Table 4).

Table 4. Comparison of values of the subscore for motor recovery of FMA for the upper extremity in the four measurement times by groups

Time of measurement	No. (N)	Average (Mean)	Std. Deviation	Min.	Max.	Percentiles		
						25th	50th (Median)	75th
Examined group - Friedman test: Chi-Square (3)=27 p=0.00001*								
Baseline	15	12.53	7.14	4	28	7	11	15
2 weeks	15	14.07	7.37	5	30	10	12	15
6 weeks	15	14.11	7.32	5	30	10	12	15
14 weeks	15	14.19	7.27	50	30	10	12	15
Control group- Friedman test: Chi-Square (3)=12.667 p=0.005*								
Baseline	15	14.07	6.64	4	30	9	15	18
2 weeks	15	15.20	6.12	8	32	11	15	18
6 weeks	15	14.73	5.94	8	30	10	15	18
14 weeks	15	14.73	5.94	8	30	10	15	18

* significant for p<0.05

The Post Hoc Test analysis of the subscore for motor recovery of the FMA for the upper extremityin the EG suggested a significant difference between baseline/control1; baseline/control2 and baseline/control3 in favor of a significantly higher value of the test at control examinations (Table 5). In the CG there wasno significant difference in the values of the subscore for motor recovery between the six analyzed combinations of times (Table 5). The comparison of the two groups in each of the four measurement timesrelated to Fugl–Meyer test value did not indicate a significant difference (p>0.05).

Table 5. Post Hoc Test of values of the subscore for motor recovery of FMA for the upper extremityby groups

Wilcoxon Signed Ranks Test	Baseline/ Control 1	Baseline/ Control 2	Baseline/ Control 3	Control 1/ Control 1	Control 1/ Control 2	Control 2/ Control 3
Examined group						
Z Asymp. Sig. (2-tailed)	(2.716) 0.007*	(2.716) 0.007*	(2.716) 0.007*	0.000 1.000	0.000 1.000	0.000 1.000
Control group						
Z Asymp. Sig. (2-tailed)	(2.226) 0.026	(1.342) 0.180	(1.342) 0.180	(1.890) 0.059	(1.890) 0.059	0.000 1.000

* in accordance with the Bonferroni correctionsignificant for $p<0.012$

Discussion

Spasticity itself is not more responsible for the functional disability after a stroke compared to the other characteristics of the central motor neuron syndrome, however it is one of the biggest obstacles we encounter during the rehabilitation process of these patients. A spastic upper extremity leads to a poor quality of life. It greatly increases the patients' difficulties during their daily self-care, but it also limits the efficiency of physical therapy and rehabilitation. It is associated with difficult and slow motor recovery of the extremity. Therefore, it is assumed that the reduction of spasticity in many cases will contribute to the improvement of the residual function.

Today, there are numerous opportunities for spasticity treatment: treatment with medications (baclofen, tizanidine, dantrolene sodium, diazepam), physical modalities (ice therapy, magnetotherapy, vibration, EMG biofeedback), rehabilitation methods (stretching of spastic muscles, active exercises for weak muscles, relaxation exercises, coordination exercises, limb positioning, Bobath technique, Kabat technique, Brunnstrom method, manual massage), chemodenervation (botulinum toxin, phenol, alcohol), surgical interventions. However, sometimes even with a combination of some of the above-mentioned methods and the presence of side effects of some of them, hypertonia reduction can not be achieved.[1,2,6] For this reason, it is necessary to consider developing a new non-invasive treatment in order to find a solution for this condition.

The results of this study have proven the benefits of RESWTin the treatment of spastic hand after a stroke. Immediately after treatment, there was a reduction in the spasticity of the hand and fingers in the examined group. The results proved that there wasno significant difference between the two groups in the individual comparison of the MAS score values in the four measurement times that may be due to the small group of respondents. However, in the examined group, a significant difference was found between the average MAS scores in the four measurement times, that is, the highest average value of the MAS score at baseline, and the lowest was after the completion of the treatment. Over time, the therapeutic effect was reduced;still even 3 months upon completion of the therapy, there was a better clinical result than the one before the start of the treatment. In the examined group, the mean valueof the subscore for motor recovery of the FMA for the upper extremity was lowest atbaseline, and in the other three times it was higher, which suggests the possible role of RESWTin motor recovery of the spastic hand after a stroke.

During and after the treatment, no side effects of the application of RESWTwere observed. The results of this study confirm the benefits of RESWT in reducing spasticity and better motor recovery after

the treatment. They correspond to the results of previous studies that deal with this issue, and document the fact that the noninvasive RESWTcontributes to a relatively long-lasting reduction in spasticity and a better motor recovery of the hand. Each of these studies presented a different protocol for treatment application.[18-31]

A unified protocol for the application of RESWTin the treatment of spasticity after a stroke has not been developed, yet. The mechanism of action of RESWTon spastic muscles isstill not sufficiently familiar. Different mechanisms of action have been proposed, one of the possible being reduction in spinal excitability and induction of mechanical vibrations.

RESWT can induce synthesis of nitrogen monoxide (NO), which plays a role in the neuromuscular junctions and is involved in neurotransmission, memory formation, and synaptic plasticity in the central nervous system. NO can increase muscle and tendon neovascularization, thereby improving muscle stiffness. NO may therefore play an important role in reducing spasticity and improving muscle stiffness. Also, there are no significant changes in F-wave minimal latency and H-reflex latency after ESWT, therefore the effect of ESWT on excitability of the spinal cord and the Golgi tendon can be excluded as the main mechanism.[20,21,27] One of the possible effects is the direct influence of fibrosis and the rheological components of the hypertonic muscles. It is considered that RESWTaffects the structural biomechanical properties of the muscle in terms of breakdown of persistent relationships between myofilaments, reduction of fibrous tissue in the muscle, and improvement of inactive connective tissue characteristics.[30,31]

Conclusion

RESWT reduced spasticity of the wrist and hand flexors after a stroke and had a positive effect in terms of a better motor outcome.No side effects of its application were observed. RESWT is a safe alternative, non-invasive treatment in reducing spasticity after a stroke. This therapy opens a new field of research in the non-invasive treatment of spasticity. Further studies are needed including alarge cohort of patients.

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