The Immediate Effect of Radial Extracorporeal Shockwave Therapy for Spasticity and Motor Function in Chronic Post-stroke Patients

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Abstract: This study aimed to report the immediate effect on spasticity and motor function of radial extracorporeal shockwave therapy (rESWT) as part of a comprehensive treatment program for chronic stroke patients with spasticity and functional problem in upper extremities. Chronic poststroke patients with spasticity on upper extremity were enrolled and got rESWT that applied at muscle belly of the biceps muscle, flexor carpi ulnaris muscle, and flexor carpi radialis muscle. Patients were evaluated for elbow flexor and wrist flexor spasticity using Modified Ashworth Scale (MAS), and for motor function using Fugl-Meyer Assessment for Upper Extremity (FMA-UE) at baseline and immediately after rESWT therapy session. 6 male and 1 female patients participated, age 59.7$\pm$5.5 years old, with mean onset time of stroke were 40.4 $\pm$ 25.2 months. The MAS score was 5.4 ± 1.5 at baseline and 4.2 ± 1.2 after the treatment ($p<0.05$). The score of motor function FMA-UE scale was 26.4 ± 9.0 at baseline and 28.6 ± 9.9 after the treatment ($p<0.05$). Radial ESWT immediately improved spasticity and motor function in some chronic poststroke patients. More studies are necessary to establish if rESWT for spasticity and motor function in chronic poststroke is clinically effective.

1 INTRODUCTION

Spasticity, commonly defined as "a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex" is a common complication in poststroke associated with other signs and symptoms of the upper motor neuron syndrome (Francisco, 2012). The prevalence of poststroke spasticity has been reported approximately 39% in patients with a first attack stroke after 12 months (Watkins, 2002), and approximately 17-25% after 3 months post stroke, 21-25% since 1-3 weeks after the attack. (Sommerfeld, 2012; Katoozian, 2018).

Poststroke patients, presented with spasticity and other upper motor neuron syndromes such as agonist/antagonist co-contraction, weakness, and lack of coordination, may have worse impairments and functional problems that can predispose other costly complications and detain rehabilitation process (Francisco, 2012; Duncan, 2005). The pathomechanism of spasticity is caused by hyperexcitability of motor neurons by augmented of excitatory synapse input and excitability of muscle spindle, reduction of inhibiting synapse input, change of nerve electrical characteristics or mechanical alteration in intrinsic muscle components (Hasuk, 2010). The main factor of the spasticity in chronic poststroke is the mechanical change of intrinsic muscle characteristics, such as structural shortening of muscles (Lundy, 2013) and muscle fibrosis (Mirbagheri, 2008). The current general treatment for spasticity consists of passive stretching, splints, oral medications, phenol injection and botulinum toxin (BTX). However, until recently spasticity therapy in poststroke patients often inadequate (Francisco, 2012).

Radial ESWT (rESWT) is a type of shock wave that is pneumatically generated, producing low to medium energy, superficial, larger therapeutic area, and more economical compared to traditional focused ESWT (fESWT) (Chang, 2012). Recent studies have reported that ESWT is a safe, non-invasive, and is an alternative spasticity therapy that does not cause muscle weakness or unwanted

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effects in patients with strokes (Santamato, 2013). The mechanism underlying the beneficial effects of ESWT on spasticity still needs to be explored. Previous studies have proposed the theory that ESWT affects the production of nitric oxides (NO) (Mariotto, 2005), decreases muscle fibrosis, modifies spinal cord excitability (Manganotti, 2005), or impacts on Golgi tendon organs or mechanical vibrations (Hasuk, 2010). Hypothetically, mechanical vibration from ESWT will cause an immediate decrease of muscle fibrosis that will modify muscle spindle excitability causing decreases the spasticity (Manganotti, 2005).

Some studies have shown that ESWT administration can reduce hand and wrist spasticity accompanied by improved wrist and hand control function in chronic poststroke patients (Li, 2016) (Guo, 2017). Even though rESWT immediate effect on spasticity poststroke using Modified Ashworth Scale (MAS) had been done in many studies (Hasuk, 2010; Li, 2016), there is no other study evaluate rESWT immediate effect on motor function using Fugl-Meyer Assessment for Upper Extremity (FMA-UE). The Fugl-Meyer Assesment is a well-designed, feasible and efficient clinical examination method that has been tested widely in the stroke population. The Fugl-Meyer motor scale is recommended highly as a clinical and research tool for evaluating changes in motor impairment following stroke (Gladstone, 2002).

Therefore, the aim of this study is to report the immediate effect on spasticity and motor function of radial extracorporeal shockwave therapy (rESWT) as part of a comprehensive rehabilitation program for chronic post-stroke patients with spasticity and functional problem in upper extremities.

2 METHODS

This is an experimental study, done at the outpatient Physical and Medical Rehabilitation Clinic of Dr. Hasan Sadikin General Hospital, Bandung, Indonesia. This study included chronic post-stroke patients with spasticity on upper extremity (MAS ≥ 1+) that persist more than 3 months after stroke. Patients with joint contracture, recently got phenol or botox injection, had malignancy, coagulopathy, infection, using pacemaker were excluded.

Each subject got rESWT (Swiss Dolorclast ® Smart20) that applied at muscle belly of the biceps muscle, flexor carpi ulnaris muscle, and flexor carpi radialis muscle. Each site had 2000 shot of rESWT with pressure 3 bar, frequency 8 Hz, applicator 36 mm^2.

Patients were evaluated for elbow flexor and wrist flexor spasticity using Modified Ashworth Scale (MAS). The maximum MAS score in this study was 5, and 1+ was converted to 2. The average MAS score was calculated as the mean MAS score of the elbow flexor and wrist flexor spasticity (Chia-Ling, 2019). Evaluation motor function was using total motor function score Fugl-Meyer Assessment for Upper Extremity (FMA-UE) with minimum score is 0 and maximum score is 66. The evaluation was done at baseline and immediately after rESWT session. Each participant signed the informed consent form. This study had been approved by the local hospital ethical review board (No: LB.02.01/X.6.5/101/2019).

All analyses were performed using Statistical Package for Social Sciences (SPSS) software ver. 17.0 (SPSS Inc., Chicago, IL, USA). A paired t-test was conducted to determine statistical differences in the variables between the pre and post treatment. Values are presented as mean±standard deviation for data with normal distribution, and $p<0.05$ was considered statistically significant.

3 RESULTS

Six male and 1 female patients were included, mean age 59.7±5.5 years. Mean time were 40.4±25.2 months after the onset of stroke. The scores of MAS improved immediately after radial rESWT in 71.4 % of patients. The MAS score was 5.4±1.5 at baseline and 4.3±1.1 after the treatment ($p=0.007$). The score of motor function FMA-UE scale was improved immediately after rESWT in 71.4 % patients. The score of motor function FMA-UE scale was 26.4±9.0 at baseline and 28.6±9.9 after the treatment ($p=0.015$)(Table 1, Figure 1).

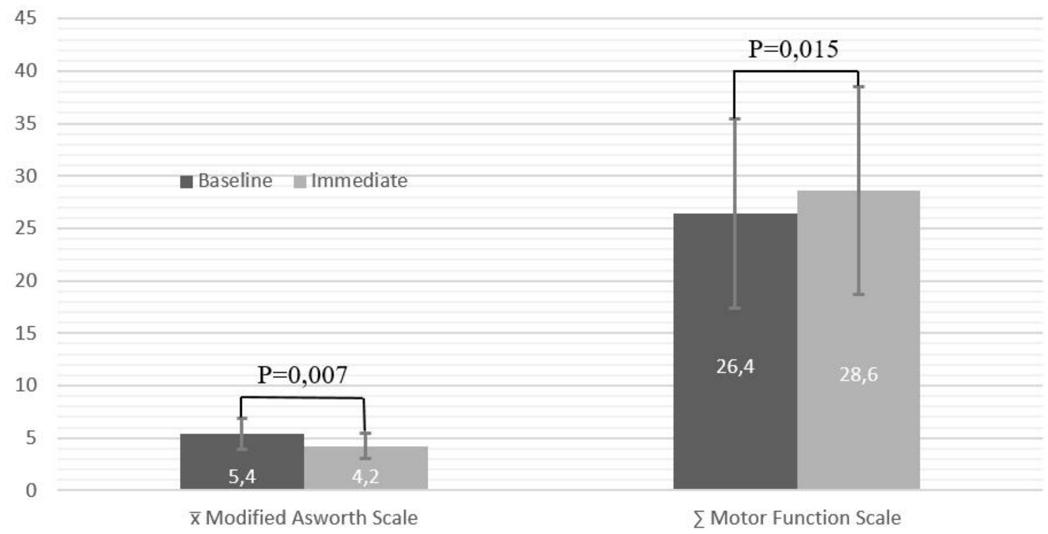

Figure 1: Immediate Improvements after rESWT.

Table 1: Results.

M: Male, F: Female, MAS-B: Modified Ashworth Scale Baseline, MAS-I: Modified Ashworth Scale Immediate, MF-B: Motor Function from Fugl-Meyer Assesment for Upper Extremity Baseline, MF-I: Motor Function from Fugl-

Subject No.	Gender (M/F)	Age (years)	Time since stroke (months)	$\bar{x}$ MAS-B	$\bar{x}$ MAS-I	∑ MF-B	∑ MF-I
1	M	53	24	4	2	18	20
2	M	65	82	6	5	41	47
3	M	54	6	5	5	13	20
4	M	50	9	3	3	21	21
5	M	61	18	8	6	16	16
6	M	65	84	8	6	40	48
7	F	70	60	4	3	36	38
mean±SD		59.7±5.5	40.4±25.2	5.4±1.5	4.2±1.2	26.4±9.0	28.6±9.9
t-test				p =0.007*		p =0.015*	

Meyer Assesment for Upper Extremity Immediate. *The result is significant at $p < 0.05$

4 DISCUSSIONS

The present study evaluated the effects of rESWT in chronic post-stroke patients with spasticity on the upper extremity in terms of spasticity improvement, and motor function features. We found statistically significant improvement in spasticity after the treatment in this study. The score change of spasticity (1.1429±0.667) in this study exceeds the minimal clinically important difference of average Modified Ashworth Scale of the effect size 0.8 standard deviations for extremity muscles which are 0.76 (Chia-Ling, 2019). This result is similar to previous study that there was immediate effect of rESWT on chronic poststroke patient's spasticity (Hasuk, 2010).

The effect of ESWT for chronic poststroke spasticity in the short-term and long-term had been studied in many studies (Suputtitada, 2018). Li et al. found that the effect of a single application of rESWT on post stroke spasticity persists at least 8 to 12 weeks, while 3 sessions of rESWT effect persist at least 16 weeks (Li, 2016). However, Hasuk et al. study had a different result. They conclude that spasticity after chronic poststroke improved immediately after rESWT, but was not changed significantly at 1 week and 4 weeks after rESWT (Hasuk, 2010). We conduct this preliminary report as a part of an ongoing, larger and long-term study about the effect of rESWT on poststroke spasticity. We intended to give additional prespective to those contradictory results about the short-term and long-term effects of rESWT on spasticity poststroke.

The spasticity can be categorized into the part by stretch reflex, as the neural component of hypertonia, and stiffness of muscle intrinsic, as the nonneural component of hypertonia. Spasticity triggered by stretch reflex progressively increases for 1-3 months after stroke and after that, it decreases, so the muscle intrinsic stiffness takes part in the main trigger of the spasticity. Over the course of time, prolonged muscle activation due to spasticity will cause muscle fiber shortening which results in increased passive stiffness that caused by increased amounts of collagen in the extracellular matrix of muscle fiber bundles (Lynn, 2015). Mirbagheri et al also found that there is neural reflex of skeletal muscle factor and intrinsic mechanical factor contribute to spasticity that is different according to the status of disease, patients' age, and duration of disease (Mirbagheri, 2008). In this study, we found that there was an immediate improvement of spasticity

after treatment in most patients, but there is no immediate improvement in 2 patients with shorter duration of disease. The muscle intrinsic factor would be the main factor in the spasticity is highly probable in patient with longer duration of diseases and there could be marked immediate effect of spasticity reduction effect by mechanical high-frequency vibration of ESWT in those patients (Manganotti, 2005; Hasuk, 2010). The reduced extensibility, due to soft tissue changes, causes pullings to be transmitted more readily to the muscle spindles. In this condition, an exaggerated spindle discharge in response to muscle stretch might lead to an increased stretch reflex. The reduction of non-reflex hypertonia could modify muscle spindles excitability, leading to a secondary reduction of spasticity (Gracies, 2005; Marinelli 2015).

The improvement of motor function from Fugl-Meyer Assesment for Upper Extremity is found in 5 of 7 patients in this study. The improvement was statistically significant when compared with the baseline. The increased score indicates improvement of the motor function of poststroke patients and in this study, the increment exceeded the minimal clinically important difference for Fugl-Meyer Assesment for Upper Extremity which is more than 4.25 in 3 patients (Page, 2012).

The upper limb function of poststroke patients is affected by many factors, such as muscle strength, muscle tone, joint disturbances, proprioception, pain, and motor control. However, spasticity and weakness are the primary reason for rehabilitative intervention in the chronic stages (Bang 2009; Gandolfi, 2019). Upper limb weakness after stroke is prevalent and determinant of upper limb function in ADLs. Literature supports upper limb strengthening training effectiveness for all levels of impairment and in all stages of recovery (Harris, 2010). Those findings were underlining the importance the neurorehabilitation treatment such as strengthening exercises for the antagonist muscles, endurance exercises, balance and coordination training for enhancement the movement ability and the functional outcome of the patients (Suputtitada, 2018).

Improvement of the spasticity from the rESWT therapy session not directly make the improvement of the upper limb function in our study. Poststroke patients with mild-moderate impairment of muscle strength with reduce spasticity seems will have greater improvement of upper limb function compare patients to one with severe impairment of muscle strength. Unfortunately, we didn’t collect data on muscle strength of each patient to conduct such analysis.

In addition, we conducted data collection for pain during and after shockwave therapy using Numeric Rating Scale (NRS) and asked if they would recommend ESWT for other patients with same condition as them because recent studies have found that ESWT application is considered painfull (Roerdink, 2017; Haake, 2002) and would make some rejection of the patients. From those data, we found that all patients reported shockwave to be painful during treatment (NRS $\geq$ 6 out of 10), but there is no post treatment pain. Furthermore, 5 of 7 patients still would recommend ESWT for other patients with same condition as them.

Our study has several limitations. First, this study had a small sample size. Second, we evaluated only the immediate outcomes. Third, there is no control group. We suggest to do a further investigation with larger sample size, with evaluation short-term and long-term effect of rESWT on poststroke spasticity with comparison to conventional therapy. The study also needed to evaluate characteristics of poststroke patient have good response to rESWT and specific regimen with regard to dose, frequency, and location of therapy that more effective to decrease the spasticity.

5 CONCLUSIONS

Radial ESWT immediately improved spasticity and motor function in some chronic poststroke patients. More studies are necessary to establish the effectiveness of rESWT in spasticity and motor function in chronic poststroke.

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