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Original Article

Knee joint angle of intracerebral hemorrhage-induced rats after extracorporeal shock wave therapy

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Abstract. [Purpose] The purpose of this study was to investigate the impact on rat knee joints of extracorporeal shock wave therapy after experimentally induced intracerebral hemorrhage. [Subjects and Methods] Sprague-Dawley (SD) rats were divided into an experimental group that received extracorporeal shock wave therapy after central nervous system injury (n=10) and a control group that did not receive any therapeutic intervention after central nervous system injury (n=10). The Dartfish program was used to evaluate the SD rats' locomotion. [Results] There was a significant difference between the control group and the experimental group in the change of knee joint angle during midstance after the intervention. [Conclusion] In conclusion, at extracorporeal shock wave therapy for central nervous system injury was confirmed to be effective at reducing knee joint angle, confirming it is a good physical therapy intervention, based on its efficacy.

Key words: Nerve injury, Knee joint, Gait

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INTRODUCTION

Intracerebral hemorrhage (ICH) is generally caused by degenerative changes related to high blood pressure or blood vessel rupture due to amyloid angiopathy of the brain and it can affect the cerebral lobe, basal ganglia, thalamus, brain stem, and cerebellum. Most hemorrhages related to high blood pressure develop at the bifurcations of small arteries stemming from basal arteries or from the front, middle, and back cerebral arteries[1, 2)].

Walking impairment is one of the representative symptoms observed in stroke patients. It develops due to impairment of the integration function of the higher centers related to lesions of the motor-sensory pathway, and the symptoms are exacerbated by spasticity, inactivity, and the non-use that occurs after nerve injury. Stroke patients may have decreased gait speed, and may require excessive effort to walk. These patients show very diverse patterns, including coordination disorders and asymmetric walking due to center-of-mass movement[3, 4)].

Asymmetric walking patterns develop due to spasticity, myoparalysis, and primitive collaboration patterns. These are caused by excessive use of the unaffected side to compensate for inadequate movement and decreased weight-bearing of the affected side. In asymmetric walking, the toe of the affected side touches the ground first, with initial contact due to the action of the extensor muscle resulting from spasticity of the affected-side lower limb. Stride length is shortened by a decreased stance phase on the affected side and a decreased swing phase on the unaffected side. The ability to propel the body forward also decreases due to spastic contracture of the triceps muscle of the calf, which consequently decreases stride length and gait speed[5)].

With regard to locomotion of the Sprague-Dawley (SD) rat after central nervous system injury, the angle of the hip, knee, and ankle joints in the initial-stance phase decrease, while the angle of the hindlimb joints at toe-off increases with time[6)].

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The stance-phase time and stride length of the affected-side hindlimb decrease more than on the unaffected-side after nerve injury[7)].

In a study by Moon et al. that examined the effects of extracorporeal shock wave therapy (ESWT) on the lower-limb spasticity of subacute stroke patients, instant improvements in Modified Ashworth Scale (MAS) scores, peak eccentric torque, and torque threshold angle were observed[8)]. With regard to the MAS score, a statistically significant change compared to the preliminary measurement was observed up to one week after the therapy. However, controlling the effects of therapy overlap in the rehabilitation of stroke patients was difficult in most previous studies. It is also difficult to generalize the effects of therapy, since the flux density, number of treatment sessions, and shock wave frequency applied to treat walking impairment, and the timing of stroke onset differed among the experimental subjects.

The present study determined the effects of applying ESWT to the affected-side hamstring muscles of SD rats after experimentally induced stroke, by measuring the knee joint angle at mid stance during walking.

SUBJECTS AND METHODS

In this study, twenty Sprague-Dawley rats (8 weeks old) were used. This experiment used the collagenase-induced model of intracerebral hemorrhage to induce ICH inside the left striatum.

Using a random classification method, the rats were divided into an experimental group that received ESWT after ICH injury (n=10), and a control group that did not receive any therapeutic intervention after ICH (n=10). The initial evaluation of the affected-side knee joint angle was conducted two days after ICH. The post-evaluation was conducted after 16 days to examine the effects of the experimental intervention. For the ESWT group, initial therapy began on the second day after ICH and was applied three times a week for two weeks. All surgical procedures and experimental protocols followed Daegu University's guidelines and were approved by the Institution of Animal Care and Use Committee (IACUC).

A magnetic-type ESWT device (HAEMIL, Soltar, Korea) was applied to the hamstring muscle of the affected-side hindlimb, with a low intensity and a PAD5 head. ESWT was applied 500 times with frequency of 3 Hz and an energy flux density of 0.06 mJ/mm^2.

The Dartfish program was used to evaluate the rats' locomotion. Recorded video images were used for the measurement of the affected-side knee joint angle. For the locomotion analysis using Dartfish, only images showing a complete step-cycle from initial contact to the next initial contact were used[9)].

The results of the data obtained in the experiments are presented as mean ± standard deviation (Mean ± SD). The paired t-test was used to examine the within-group changes in knee joint angles. The independent t-test was conducted to examine the between-group differences of the effects before and after the intervention. SPSS version 20.0 was used for data analysis with a statistical significance level, α, of 0.05.

RESULTS

In the within-group comparison of knee joint angles during the mid stance before and after the intervention, both the control group and the experimental group showed significantly increased knee joint angles ($p<0.05$) (Table 1). There was a significant difference between the control group and the experimental group in the change of knee joint angle during mid stance after the intervention ($p<0.05$). The experimental group that received ESWT showed a significantly smaller change in knee joint angles during mid stance then the control group ($p<0.05$).

DISCUSSION

ESWT is a nonsurgical method that destroys calcifications and damaged cells, and regenerates damaged tissues by focusing shock wave energy on one point[10)]. Although the exact mechanism of the action of external shock wave energy has not yet been clarified, recently published theories postulate microtrauma and cognitive decline of the central nervous system that recognizes chronic pain. ESWT relieves pain and promotes local blood vessel remodeling and cell regeneration, and is effective at decreasing muscle tone and increasing muscle strength. It is used in treatments for tendinitis, peritenonitis, myofasciitis, and pelvic pain syndrome. Studies have also reported positive results for ESWT in the treatment of epicondylitis and myofascial pain syndrome[11)].

Previous studies on the effects of ESWT on nerve injury have been performed. Manganotti and Amelio examined the ef-

Table 1. Comparison of knee joint angles between pre-test and post-test (Mean ± SD)

	Pre-test (°)	Post-test (°)	Variation*
Experimental group (n=10) *	65.1 ± 9.6	76.6 ± 8.4	10.32 ± 2.67
Control group (n=10) *	67.5 ± 8.1	82.3 ± 10.2	15.46 ± 3.64

*$p<0.05$

fects of ESWT on muscle hypertonia among stroke patients, and found that hypertonia significantly decreased after 12 weeks of ESWT[12]. A later study by the same authors examined the effects of ESWT on hypertonia of the plantar flexor muscle of children with cerebral palsy, and found that the range of motion and surface area of the ankle plantar flexor began to increase four weeks after the treatment. As such, ESWT is being applied in diverse areas, and the application field is expanding because of the efficacy of this therapy.

Santamato et al. that examined the impact of ESWT on foot-drop after stroke, by assessing the spasticity and the angle of passive ankle dorsiflexion. ESWT applied to the gastrocnemius significantly decreased lower-limb spasticity and increased passive ankle dorsiflexion[13]. That study proposed the safety of ESWT, reporting that there was no abnormal excitation of the spinal cord on the Heckmatt scale, according to sonography performed 30 days after the therapy.

The results of the present study show there was a statistically significant difference between the experimental group that received ESWT and the control group with regard to changes in knee joint angles during walking. The change in knee angle at mid stance in the experimental group was significantly smaller than that of the control group.

In a study that examined the impact of ESWT on MAS scores for the ankle plantar flexors and biological markers of hemiplegic stroke patients, the MAS scores significantly decreased after an application of ESWT to the middle of the muscle belly of the gastrocnemius, while the marker of skeletal muscle rhabdomyolysis showed no change[14].

The present study had limitations in that the results are difficult to generalize to human subjects since the experiment was conducted on rats. Also, as the post-evaluation was conducted two weeks after the initial evaluation, changes in the rats' locomotion ability after nerve injury were not observed at more detailed intervals. We hope that future research will incorporate segmented and continuous evaluations to address the limitations of the present study.

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