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Correlation between Affected Arm Muscle Activity and Global Synkinesis in Patients with Stroke

Background: Although there are interventions available for the improvement of arm functions of patients with stroke, measuring changes in global synkinesis (GS) according to changes in the muscle activity of paretic and nonparetic side muscles is an important factor and studies to investigate such potential factors are evaluated necessary.

Objective: To examine the correlation between the affected arm muscle activity and GS changes in patients with stroke.

Design: Randomized controlled trial

Methods: In order to measure muscle activities of 30 stroke patients, anterior deltoid, posterior deltoid, biceps brachii and triceps brachii of the affected arms were measured using surface electromyography (EMG) and for analyzing GS, biceps brachii and triceps brachi of the affected arms were measured using the same instrument.

Results: When the correlations between the muscle activity and GS of the affected arm were analyzed, the results showed significant correlations between the posterior deltoid and the triceps brachii($p < .01$) and between the triceps brachii and GS($p < .05$).

Conclusion: : The results of this study suggest that the efficient movements of the affected arms of stroke patients, it is possible to increase extensor activity by improving smooth antagonism of the arm.

Key words: *Stroke, Muscle Activity, Global Synkinesis*

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INTRODUCTION

Stroke is a serious disease and also the second most frequent cause of death throughout the world, which makes patients have physical disabilities for long periods of time [1]. The severity of stroke is constantly raised because 50% of patients diagnosed with stroke are subject to deterioration of the quality of life and limitations in the use of the arm [2], and the arm functions are recovered only in 5% ~ 20% of the patients even with interventions for the improvement of arm functions [3, 4]. Factors responsible for arm dysfunction include spasticity, cramp in flexor and extensor muscles, muscle weakness, loss of agility, and abnormal muscle activation because of simultaneous contraction of agonistic and antagonistic muscles [5]. In particular, excessive muscle tone acts as a factor that hinders the recovery of arm functions and return to daily life by negatively affecting the ability to carry out daily living activities by inducing involuntary muscle contraction and hindering normal arm movements [6].

Involuntary movements of the affected arm may appear when the nonaffected arm is voluntarily moved in about 30% cases of hemiplegia. In such cases, the action of the muscles of the affected arm appears simultaneously with the action of the muscles of the nonaffected arm [7]. This phenomenon is referred to using diverse related terms such as “global synkinesis(GS)” [8], “mirror movement” [9] and “motor overflow” [10-11] because there are difficulties in classification because the phenomenon is mixed with the concept of movements, indicating involuntary muscle activity. Not only homologous involuntary movements but also unintended movements of other regions are inadequately suppressed [12, 13]. GS is also a common phenomenon observed during the developmental stage in childhood before the age of 10 years or in healthy adults while they carry out complicated work or exercise at maximum strength or speed [14]. It has been said that although GS is a normal reaction during the development stage in childhood, it can recur in pathological conditions such as stroke [15]. The response of GS obstructs the recovery of the performance of movements and functions and appears as a consistent pattern in patients with brain damage [8]. However, the two factors, that is, the simultaneous activation of the primary motor area and the activation of ipsilateral cerebral cortex pathways by GS related to degenerative neuronal diseases are emphasized as pathological causes [15, 16].

To make functional movements appear in the arms of patients with stroke, accurate motor tasks can be carried out through appropriate muscle activity and coordination [17]. However, these patients are limited in their ability to carry out daily living activities due to the abnormal pattern of muscle activation of the affected arm and wrong timing in the pattern [18, 19]. Electromyography can be applied as an evaluation method for the recovery of motor function because it enables the objective measurement of muscle activation and analysis of the quantity of pattern of muscle activation [20, 21]. Many studies investigated muscle activation and patterns in patients with stroke, using electromyography, to report abnormal simultaneous contraction patterns [22, 23]. However, although many exercise methods for the functional recovery of the affected arm of patients with stroke have been presented, even after intervention, these patients have abnormal patterns in daily living activity motions because of irregular muscle contraction and tone.

Although there are interventions available for the improvement of arm functions of patients with stroke, measuring changes in GS according to changes in the muscle activity of paretic and non-paretic side muscles is an important factor and studies to investigate such potential factors are evaluated necessary. Therefore, this study intends to provide important factors that would enable measuring the degree of efficient recovery of the affected arm of patients with stroke as basic data that can be used at clinics through correlation analysis on the basis of the correlation between changes in the activity of muscles around the affected arm and changes in GS.

SUBJECTS AND METHODS

Subjects

This study was conducted from April to July 2019 after being approved by the institutional review board (SH-IRB 2019-31), with 30 patients hospitalized in J Hospital located in Jeollanam-do, South Korea. The study subjects were selected from those hemiplegic patients diagnosed with stroke who were attacked by stroke between 6 months and 2 years ago, were found to have no limitation in a manual test of the joint range of the affected arm, had no other neurologic or orthopedic disease in any of the two arms, were found to be at least Brunnstrom stage 4 for the recovery of the hand, obtained at least 24 points in a mini-mental state examination—Korean version so that they could understand and follow the researcher's instructions, and were found to be at least fair in manual muscle testing. General characteristics of this people are presented in Table 1.

Intervention

Forty hemiplegic patients diagnosed with stroke were recruited, and thirty samples were extracted through subject screening tests from among those hemiplegic patients who were attacked by stroke between 6 months and 2 years ago, had normal cognitive

Table 1. General characteristics

Items	Subjects (n = 30) M±SD	p
Age(year)	63.25±4.09	.146
Height (cm)	163.75±5.03	.202
Weight (kg)	76.71±2.96	.917
BMI (kg/m2)	29.42±1.62	.97
MMSE-K (score)	26±.7	.143

BMI: body mass index, MMSE-K: mini-mental state examination—Korean version functions, and were found to be at least Brunnstrom stage 4(synergy are mastered, first with difficulty, then with more ease, and spasticity begins to decline.) for the recovery of the arm and at least Brunnstrom stage 3(Mass grasp; use of hook grasp but no release; no voluntary finger extension; possibly reflex extension of digits) for the recovery of the hand. Using the surface electromyography MP100 equipment (Biopac Systems, CA, USA), the activity levels of the anterior deltoid, posterior deltoid, biceps brachii, and triceps brachii were measured. Thereafter, the GS of the biceps brachii and triceps brachii of the affected arm was measured using the same equipment and the results were analyzed.

Measurement of arm muscle activity

Four channels of the surface electromyography MP100 were used to measure arm muscle activity. The sampling rate for collection of electromyography signals was set to 1,000 Hz, and the frequency band filter was set to 30~450 Hz. Hair and dead skin cells were removed from the skins of the subjects, using a fine sandpaper, to minimize skin resistance to electromyography signals, and the skins were cleaned by rubbing alcohol swabs on them. Thereafter, two Ag/Agcl surface electrodes were attached to the muscle belly of each muscle in the direction parallel to the muscle fibers at a space of 2 cm. The muscle activity levels of the anterior deltoid, posterior deltoid, biceps brachii, and triceps brachii of the affected arm were measured. As for the measurement method, after asking the subjects to take a comfortable sitting position as a reference motion, electromyography signals were collected for 10 seconds while the comfortable sitting position was being maintained. The measurement was repeated three times, and the values of 4 seconds section except for the 3 seconds at the beginning and the 3 seconds at the end were averaged and the average value obtained as such was set as the effective amplitude value during the reference motion. As for the effective amplitude value during a certain motion, the subjects' motion to stretch the arm toward an empty 500ml water bottle on the desk was measured for 10 seconds. The measurement was repeated three times, and the values of 4 seconds section except for the 3 seconds at the beginning and the 3 seconds at the end were averaged and the average value obtained as such was set as the effective amplitude value during the certain motion. Thereafter, to normalize the muscle activity levels, % RVC was used to divide the effective mean amplitude value during the reference exercise by the effective mean amplitude value during the specific exercise and convert the result into a percentage. A rest time of 2 minutes was equally applied after each measurement session.

Measurement of the global synkinesis of the arm

Two channels of the surface electromyography MP100 were used to measure Global synkinesis(GS). The sampling rate for collection of GS signals was set to 1,000 Hz and the frequency band filter was set to 30~50 Hz. Hair and dead skin cells were removed from the skins of the subjects, using a fine sandpaper, to minimize skin resistance to electromyography signals, and the skins were cleaned by rubbing alcohol swabs on them. Thereafter, two Ag/Agcl surface electrodes were attached to the muscle belly of each muscle in the direction parallel to the muscle fibers at a space of 2 cm. As for the signal collection method, signals were collected while the subjects carried out unaffected-side maximum voluntary isometric muscle contraction toward elbow flexion for 3 seconds, and the measurement was repeated three times. The muscles measured were the biceps and triceps brachii of the affected arm. During the measurement, the subject comfortably sat on a chair with arm rests and took a position in which the shoulder joint of the unaffected arm was bent 0 degrees, the elbow was bent 90 degrees, and the forearm was supinated; wore an aid so that the arm would not move; and the trunk of the subject was fixed to suppress compensation.

Data analysis

The data in this study were processed using SPSS 20.0 (IBM Corp, Armonk, NY, USA) for Windows. The Shapiro-Wilk test was used to test the normality of the general characteristics of the subjects, Pearson's correlation analysis was used to test if there are correlations between dependent variables by group, and the significance level was set to $\alpha = 0.05$.

RESULTS

The muscle activity of the posterior deltoid and triceps brachii showed a significant positive correlation. GS sshowed a significant positive correlation with the triceps brachii(Table 3).

Table 2. Mean and standard deviation of the experimental group

Items	Subjects (n = 30) M±SD
GS	2.33±2.1
Anterior deltoid	14.04±3.49
Posterior deltoid	61.99±17.69
Biceps brachii	82.80±12.74
Triceps brachii	102.02±23.38

GS: global synkinesis

DISCUSSION

In this study, to investigate the wrong coordination ability of patients with stroke due to the abnormal muscle activation patterns of the affected arm, the correlations between the activity levels of the muscles around the affected arm of these patients and Global synkinesis(GS) were compared, and to provide clinical basic data for the performance of functional movements, the following discussion is set forth.

Patients with stroke lack coordination ability because of muscle tone abnormality-related motor functions. In particular, if spasticity—which is a cause of GS symptoms—is not intervened, the muscle tone would increase further and might lead to contracture as a secondary change [24].

In a study of the correlation between the characteristics of GS and arm functions, Hwang et al. [14] reported that when they examined the activity of the action potential appearing in the unaffected arm with electromyography, the higher the level of GS in the arm was, the more positive changes for the improvement of arm functions appeared. And, in a study conducted by Ohn et al., [25] the researchers suggested that on the basis of the results of measurement of the muscle contraction patterns of the arm of hemiplegic patients, controlling the muscle tone of the abnormal flexor muscle of the elbow joint is an important element for the recovery of arm function. In addition, Motta-Oishi et al [26]. reported that taking a position when the muscle tone of the flexor muscle of the hemiplegic arm would directly affect the deterioration of the muscle and joint patterns and suggested that preventing abnormal muscle tone is essential. In this study, the GS and activity of the flexor muscle of patients with stroke did not show any significant correlation so that the muscle tone of the flexor muscle of the affected arm could be interpreted to have increased, leading to a finding contrary to the previous studies. However, since the correlation coefficient had a negative value, it is considered that if the samples of the subjects were increased and the correlation coefficients were compared, statistical significance should have been yielded.

Hu et al [27]. reported that when the degree of recovery of motor control processes of elbow and shoulder joints of patients with stroke was examined through training on elbow joint flexion and extension, it could be seen that the muscle activity of the anterior deltoid decreased further than that of the posterior deltoid. This indicated that training was efficient for the suppression of excessive muscle tone of the shoulder and also reported that the decrease in the muscle activity of the biceps brachii was also helpful for the improvement of the coordination of the arm. In this study too, the triceps brachii was shown to be the mostclosely correlated with the posterior deltoid of the affected arm, indicating the correlation of the extensor muscle thereby supporting the previous studies,

Table 3. Correlation between GS and muscle activity in the experimental group

	Experimental group (n = 30)				
	Anterior deltoid	Posterior deltoid	Biceps brachii	Triceps brachii	GS
Anterior deltoid	1.				
Posterior deltoid	-.285	1.			
Biceps brachii	.412	-.26	1.		
Triceps brachii	-.296	.905**	-.175	1.	
GS	-.028	.655	-.535	.685*	1.

* $p < 0.05$

muscle thereby supporting the previous studies, which reported that increases in the muscle activity of extensor muscles are helpful for the improvement of arm movements.

Hu et al [27]. reported that in the case of patients with stroke, the muscle tone of the flexor muscle was higher than that of the extensor muscle and muscle weakness was more frequently observed in the extensor muscle than in the flexor muscle. Park [28] indicated that when patients diagnosed with chronic stroke performed task-oriented training, the muscle activity of the anterior deltoid and triceps brachii—which are motor muscles for shoulder flexion and elbow extension—increased, whereas the muscle activity of the posterior deltoid and biceps brachii decreased because of the action of antagonistic muscles so that smooth movements appeared in daily living activities. In this study, the correlation between GS and the extensor muscle showed a positive value, and GS showed a significant correlation only with the triceps brachii. Therefore, in the case of patients with stroke, since the muscle strength of the extensor muscle is an important element for the suppression of the muscle tone of the flexor muscle of arm, it is judged that if the extensor muscle is improved, GS would increase to act as a positive factor.

Cuesta-Gómez et al [29]. found that when elbow extension increased, the targeted motor ability improved, and Keller et al [30]. stated that as the activity of the triceps brachii increased for elbow extension, positive effects for functional movements might appear. In addition, in a study conducted by Wright et al., [31] the researchers stated that if abnormal movements appear when the arm of patients with stroke moves because of the occurrence of involuntary simultaneous contraction of the agonistic and antagonistic muscles, selective movements cannot be carried out. In this study, since GS showed a statistically significant correlation with only the triceps brachii, it is considered that the suppression of abnormal flexor muscle contraction and involuntary simultaneous contraction would produce positive effects for arm functions by achieving smooth antagonism of the elbow joint.

The limitations of this study are that the findings cannot be safely generalized to all hemiplegic patients diagnosed with stroke because the study subjects were limited to only one medical institution, that variables may occur because the medicines currently administered could not be easily controlled, and that the daily lives of the subjects could affect the results of the study because the daily lives could not be controlled.

CONCLUSION

This study examined the correlations between the activity of muscles around the arm of hemiplegic patients diagnosed with stroke and GS. As for the correlations between the activity levels of muscles around the arm of patients with stroke, correlations appeared between the posterior deltoid and the triceps brachii. As regards the correlations between the muscle activity and GS, to improve smooth antagonism by suppressing abnormal muscular contraction of the arm of patients with stroke, the activity of extensor muscles should be increased. In particular, GS was improved as the activity of the triceps brachii increased. Therefore, for effective functional recovery of the affected arm at clinics, it is judged that multilateral therapeutic intervention methods should be implemented, focusing on the increase in the activity of the triceps brachii.

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