The effects of strengthening exercise of paretic lower limb extensors on the corticoreticulospinal tract in stroke

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Pupose The purpose of this study was to investigate the effects of strengthening exercise of paretic lower limb extensors on the corticoreticulospinal tract in stroke. ***Methods*** The subjects were 8 stroke patients(4 male, 4 female), training performed a 30 minutes/day, 7 days/week, for 4-week. The motor function measured by TUG, BBS, Lower MI and tract volumes of CRST analysis by DTI. ***Results*** The pre and post-training showed TUG score was significant, but BBS, Lower MI was no significant. The tract volumes of CST was increase, but no significant. The tract volumes of CRST was decrease, but no significant. ***Conclusion*** It was changes of tract volumes showed no significant, but post training, motor function showed significant. These findings will be resourceful in providing various clinical impacts in actual treatments.

Key words Chronic stroke, corticoreticulospinal tract, diffusion tensor imaging. dti, strengthening

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Ⅰ. Introduction

The impairment of motor function after a stroke is the most common problem associated strokes; approximately 50% of stroke patients experience motor paralysis(1-3). Engraft et al. noted that muscular weakness in the affected lower extremity plays an important role as a major limiting factor in the mobility of patients with chronic hemiplegia in the lower extremities(4). The conventional treatment methods used in clinical practice for gait training of stroke patients include Bobath and proprioceptive neuromuscular facilitation (PNF), which focus on the correction of abnormal muscle tension and asymmetric movement patterns, among various other factors causing gait abnormalities(5). These treatment methods consist mainly of muscle-strengthening exercises, inducing weight loads and shifts, and inducing movements using sensory stimuli in a static state through manual contact. Therefore, these treatments require significant investments of time and human elements(6). In a study on hip muscle strength and gait, Nadeau et al. found a special relationship between neurological and functional impairment due to stroke and stable gait velocity(7).

This study concluded that stroke patients' gait velocity is determined by the muscular strength of hip flexors and extensors and plantar flexors and that there is a high correlation between the muscular strength of knee extensors and gait stability(7).

Gang gwon-young stated that hip extensors increase walking gait velocity and significantly help control the stability of knee joints and maintain proper posture, and weakening of the hip extensors makes it difficult to shift the weight of the lower extremities forward(8).

Therefore, the extensors of the lower extremities are essential for safe walking.

The most important nerve related to movement in the human body is the corticospinal tract(CST)(9). It is involved in voluntary movements of the distal parts, particularly elaborate hand movements(9). The main role of another important nerve, the corticoreticulospinal tract(CRST), is to control the proximal trunk muscles, and it plays various roles in gait function (10-13).

In recent years, the development of radiological techniques for neurological analysis has made it possible to quantify nerve damage and examine it in more detail. One of these new techniques, diffusion tensor tractography (DTT) using diffusion tensor imaging (DTI), enables detailed, three-dimensional visualization of the neural tracts in the subcortical region, which has subsequently made it possible to accurately measure the location of local lesions or injuries such as stroke, traumatic brain damage, and tumors(9,14-16). This study will investigate the relationship between the CRST, which is the most important nerve for human gait functions, and treatment using manual contact. It aims to examine the effects of therapeutic intervention on the recovery of motor neuron functions and neural tracts in the CRST using DTT, and to provide basic data for easily comparing post-intervention effects.

Ⅱ. Materical and Methods

1. Subjects.

study’s subjects were ten outpatients or inpatients at Daejeon Medical Care Hospital in Daejeon Metropolitan City, and the selection criteria were as follows:

1) All subjects were under the age of 80. 2) It was at least six months after the onset of the subjects' illness. 3) The subjects had no medical history of recurrence of the disease. 4) The subjects could follow the therapist's instructions without difficulty. 5) The subjects had no contraindications to magnetic resonance imaging (MRI). 6) The subjects did not have orthopedic or neurological problems that could affect balance or the recovery of gait.

2. Study design

This study was conducted on stroke patients for a four-week period and was designed as follows:

3. Outcome measure

1) Motor function

(1) Time Up and Go Test(TUG)

The TUG evaluates the subject's functional movement, mobility, and dynamic balance(17). The mean value of three consecutive measurements was used for statistical analysis. This score was related to the gait velocity, and the level of confidence was r= -0.55(17).

(2) Burg Balance Scale(BBS)

The subject's dynamic balance ability was evaluated in three main domains: sitting, standing up, and changes in standing posture. A total score of 56 points was possible. A higher score indicates a higher level of balance ability. The analysis showed high intra-rater reliability (r=0.99) and inter-rater reliability (r=0.98)(18).

(3) Motricity index, MI

This test was designed to measure the muscular strength of the affected upper and lower extremities in stroke patients, and the total possible score was 100 points(19). Measurements were taken twice a week, and the mean value of the two measurements was used(20).

2) Tract analysis

(1) Magnetic resonance imaging(MRI)

The MRI equipment of Magnetom Skyra, which is a Time+Dot System developed by Siemens, was used for this analysis. Three-dimensional images of the brain were used as basic data for DTT.

(2) Diffusion tensor image(DTI)

Diffusion tensor imaging is an MRI technique. It is an analytical method that enables three-dimensional analysis and visualization of neural tracts in the central nervous system by measuring the diffusivity of water molecules(14). In recent years, it has drawn attention as a source of data for clinical evaluations of stroke and brain-injured patients(14). For the analysis of neural tracts in the CST, the seed region of interest (ROI) was defined as the pyramidal portion of the medullar, and the target ROI was defined as the CST in the front of the pons(21,22). For the analysis of neural tracts in the CRST, the seed ROI was defined as the reticular formation of the medullar, and the target ROI was defined as the midbrain segment(21,22). The tract volume represents the voxel of neural tracts and influences the total number of fibers(23).

4. Interventions

All subjects in this study were treated with neuro-developmental treatment for the central nervous system(24), and the exercise program for strengthening lower-extremity extensors on the affected side focused on the hip extensors(25,26). The target extensors for this program were the hip abductor and knee extensor(26). The program was implemented in a supine position, side-lying position(25), and standing position seven times a week for 30 minutes each time over a four-week period. 1) In a supine position, the subject lifts the hip by performing a posterior pelvic tilt on the affected side so that the gluteus maximus is contracted. 2) The subject lifts the hip higher while maintaining motion so that the gluteus maximus is contracted even more. 3) The subject moves from the above motion to a lateral position to contract the hip extensor and abductor, keeping the sole of the foot in continuous contact with the mat. 4) To further activate the lower-extremity extensors, the subject performs ankle dorsiflexion, pushing the therapist with the heel so that the muscles in the proximal portion of the hip joint are contracted more. 5) The subject performs knee stretches while maintaining the lateral position to further strengthen the lower-extremity extensors. 6) The subject stands on one foot by lifting the unaffected leg in a standing posture to activate the lower-extremity extensors on the affected side. 7) The subject continues to contract the lower-extremity extensors by lifting the unaffected arm to further strengthen the extensors on the affected side.

5. Statistical analysis

SPSS 18.0 for Windows was used for statistical analysis. The Wilcoxon Sign Ranks Test was performed to determine whether there were significant differences before and after the intervention. The volume of the affected nerves before and after intervention was obtained and compared. Spearman's correlation coefficient was performed as a bivariate correlation analysis on the relationship between changes in the volume of the affected nerves and changes in motor functions (TUG, Lower MI, BBS) to identify the correlation between nerve volume and motor functions. The statistical significance level was set at $\alpha=0.05$.

Ⅲ. Results

1. Participants

The general charactoerlistics of participatants was showed in Table 1. A total of 8 participate in the study(4 males and 4 females). There were mean of ages 50.71±14.71, mean of on set 46.38±18.09(month), infarction 4(50%), hemorrhage 4(50%), left hemiplegia 7(87.5%), right hemiplegia 1(12.5%).

2. Motor function and Changes of Tract volumes

1) TUG and Tract volumes

The pre and post-training showed TUG score was decrease. Changes of TUG score was 6.11~112.65%, significantly decreased($p<0.05$).

showed a significantly difference($p<0.05$).

2) BBS and Tract volumes

The pre and post-training showed BBS score was no changes. Therefore changes of BBS score was no changes.

3) Lower MI and Tract volumes

The pre and post-training showed Lower MI score was increase. Changes of Lower MI was 0~33.3%, significantly increase($p<0.05$).

The pre and post-training showed no significant, in CST and CRST, tract volumes of CST and CRST showed no significantly difference($p<0.05$).

3. DTI comparison

1) Tract volumes of CST

The pre and post-training showed no significantly difference. On the rather lesional showed tract volume ratio was increase(8.77% to 12.31%). Changes of tract volume showed contralesional was decrease(-9.79%) and lesional was decrease(-105.46%). In orther hands results were obtained increase of contralesional 3 out of 6, increase of lesional was 4 out of 6. Both increase was 2out of 6, both decrease was 1 out of 6.(Table 1)

2) Tract volumes of CRST

The pre and post-training showed no significantly difference. On the rather lesional showed tract volume ratio was decrease(66.14% to 56.29%). Changes of tract volume showed contralesional was increase(13.98%) and lesional was decrease(-1.46%). In orher hands results were obtained increase of contralesional 4 out of 6, increase of lesional was 3 out of 6. Both increase was 2out of 6, both decrease was 1 out of 6.(Table 1)

IV. Discussion

This study studied the effects of strengthening exercise of paretic lower limb extensors on the CRST in chronic stroke. CRST is known primarily for playing the role associated with walking in the human body.(27) The CST was function as a major pathway for motor control.(28,29) Based on this study, studies have studied how the effects of strengthening exercise of paretic lower limb extensors on the CRST.

1. Relationship between strengthening exercise of lower limb extensors and recovery of motor function

The pre and post-training exercise, TUG was significant as 0.028, but there was no significant difference between Lower MI and BBS. In a recently reported study by Yeo and Jang(22), CRST was associated with proximal motor function and gait, and concluded that it is important for stroke rehabilitation. This may be the basis for supporting the relationship between the extensors of lower limb strengthening exercise program and motor in but usually occurs within the first few months after onset(30). Recovery of gait and motor function is known to occur most often within 6 months after the onset of stroke(31). However, the mean age of onset was 46.375±18.090 months, which is difficult to generalize to previous studies. But, studies have shown that the statistical significance of TUG in motor function can be explained by the mechanism of functional recovery in stroke patients. This can be said to be in agreement with the study that the degree of recovery depends on the presence of external environment and rehabilitation, and the motivation of the patient(31).

Jang et al(32)., have shown that the increase of tract volume of CRST plays an important role in the walking ability of stroke patients, and has a positive correlation with MI, which is a strength test in chronic stroke patients. However, this study result in MI was not statistically significant and there was no correlation. This in not consistent with the above study because all subjects in this study were able to walk independently.

2. Relationship between strengthening exercise of lower limb extensors and CST, CRST

In both the CST and CRST tract volume changes, patient 1 showed a decrease in CST and CRST, patient 2,3 showed an increase in CST, a decrease in CRST, patients 4,5,6 showed an increase in tract volume changes of CST and CRST. The increase in the tract volume of CST has been reported in several previous studies to be able to walk after complete CST of stroke patients. However, CST cannot be associated with walking ability(33).

CRST is known to exist in both hemispheres, and thus may have bilaterally(34).

In addition, mild muscle weakness in the extremities may be associated with mild damage to other pathway in motor function, particularly, with lateral CST(22). This can support the results of our study of increased tract volume in CST and reduced tract volume in CRST.

The contralesional tract volume increase can be explained by ipsilateral motor pathway(35). The ipsilateral motor pathway is a normal motor function pathway, one of the mechanisms of recovery after stroke is demonstrated by fMRI and DTT that the motor pathway recovered from the contralesional cerebral cortex through the ipsilateral motor pathway. Jang et al(35)., concluded that the increase of the tract volume of the contralesional is a compensation mechanism of the contralesional cerebral hemisphere as a mechanism of recovery of the walking ability after stroke in the walking ability of chronic stroke patients(24,17). Therefore, in this study, we can support the increase of tract volume of contralesional CRST.

There was no statistically significant difference in the tract volume of the CST after the hip extensor strengthening exercise. The changes of the tract volumes of the contralesional and lesion showed a negative changes in pre and post-training On the other hand, CRST showed a changes in the positive value of contralesional and a changes in negative value of the lesional post-training. This is because the main function of the CST is to control the movement of the limbs, especially the exquisite movement of the hand(22) the exercise program in this study is the extensor strengthening exercise of the lower limbs, so it can be said that the results of the changes of the positive value in CRST.

Therefore, it can be concluded that CRST is related to the weakness of shoulder, proximal joint, and lower limbs compared to CST, Jang et al(32,36)., Do et al. Also demonstrated that proximal muscle weakness in patients with cerebral infarction is associated with CRST(37).

V. Conclusion

The purpose of this study was to investigate the relationship between the CRST, a neural tract in the brain, and nerve volume by performing lower-extremity extensor strengthening exercises on the affected side. A correlation was found between the lower-extremity extensor strengthening exercises, the intervention program implemented in this study, and the CRST.

Specifically, the recovery of gait ability after a stroke led to increases in nerve volume on the contralesional side of the CRST.

This result coincided with that of a study by Jang et al. and was interpreted as a compensatory action of the contralesional hemisphere as a mechanism for the recovery of gait ability after a stroke(23). This study has some limitations. First, it involved a small number of subjects. Second, it was conducted on chronic patients. Third, although the output of DTI can be expressed in quantitative values, it has limitations such as the complexities of its use and process and reliance on the analyst. Nevertheless, it may be essential for clinical evaluations and research on correlations(4).

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Table 1. Diffusion tensor image parameters.

(volume unit=mm³, ratio=%)

		patient	corticospinal tract Tract volume		Tract volume	dTv les.	dTvR cont.les.
lesional	pre	1	8	contra	687	-700	14.02
	post		11	lesional	799		
	pre	2	10		389	52.38	-23.10
	post		21		316		
	pre	3	113		712	55.51	13.49
	post		254		254		
	pre	4	70		773	69.70	37.96
	post		231		1246		
	pre	5	38		858	56.32	-5.41
	post		87		814		
	pre	6	64		814	-105.46	-9.79
	post		24		416		
			corticoreticulospinal tract				
lesional	pre	1	386	contra	316	-60.17	-23.92
	post		241	lesional	255		
	pre	2	174		183	-59.63	35.79
	post		109		285		
	pre	3	473		574	-16.50	9.03
	post		406		631		
	pre	4	326		654	10.93	-26.50
	post		366		517		
	pre	5	51		522	85.87	33.76
	post		361		788		
	pre	6	153		407	30.77	55.71

post	221	919

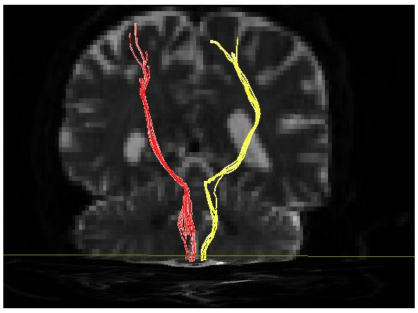
dTvR=differnce postTvR - preTvR TvR=lesionalTv/contralesional.Tv*100,

dTvR(lesional.)=changes of lesional.TvR, dTvR(contralesional.)=changes of contralesional.TvR,

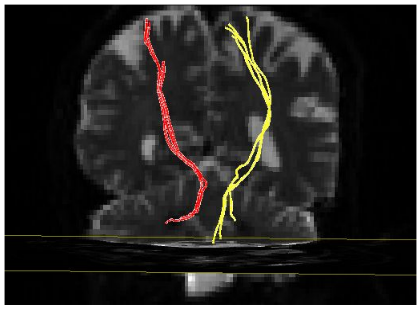
dTvR(lesional.)=((post Tvlesional.-preTvlesional/Tvlesional.)x100),

dTvR(contralesional.)=((postTvcontraleional.-preTvcontralesional./Tvcontralesional.)x100)

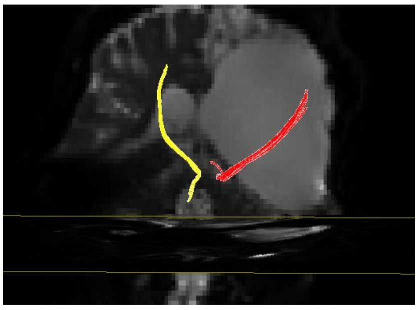
1

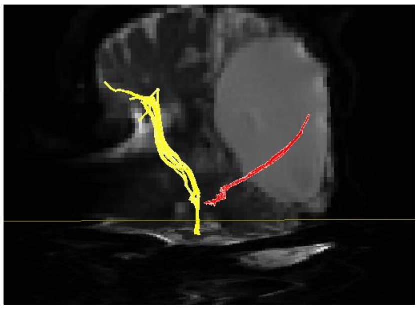


pre-training



post-training

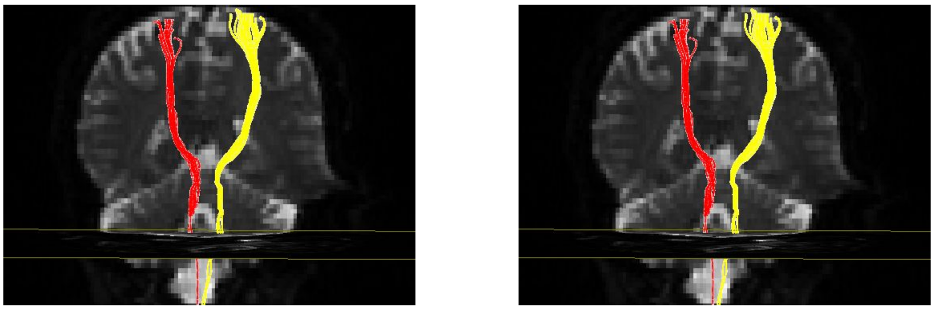




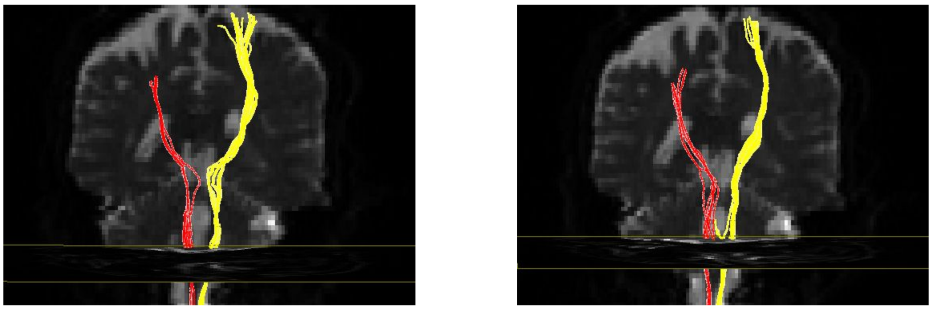
2

pre-training

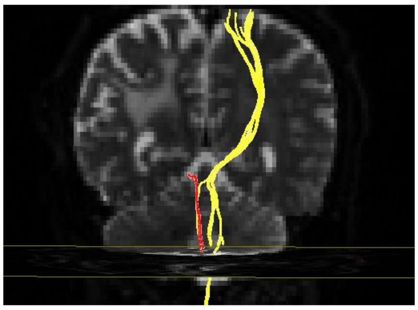
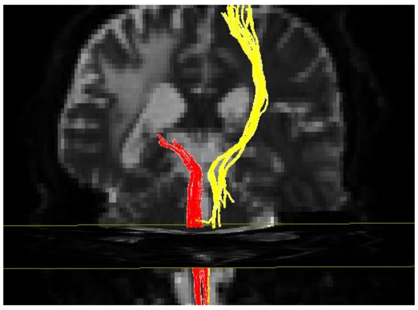
post-training



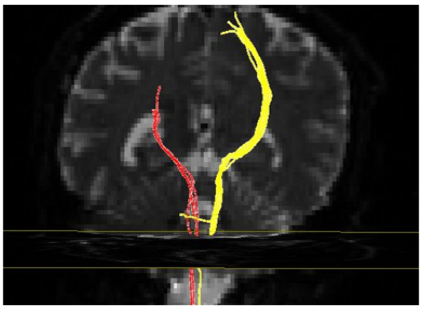
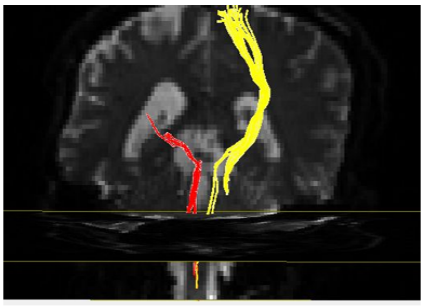
3 pre-training post-training



4 pre-training post-training

5  

pre-training post-training

6  

pre-training post-training

Figure 1. Tract volume images of corticoreticulospinal tract.

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