

The Effects of Neuromuscular Electrical Stimulation on Swallowing Function in Acute Stroke Patients with Dysphagia

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ABSTRACT

In this study, we investigated the effects of neuromuscular electrical stimulation (NMES) on the treatment of 20 acute stroke patients with dysphagia. For both the treated and control groups, the basic facial stimulation training was conducted for 30 minutes, five times a week, for four weeks. NMES was performed on the treated group only, for 30 minutes each time. Both groups were evaluated according to the functional dysphagia scale (FDS) using a videofluoroscopic swallowing study (VFSS). After the treatment was performed for four weeks, the FDS results of the treated group showed a significance difference in oral transit time in the oral phase and in the triggering of pharyngeal swallow fluid, laryngeal elevation and epiglottic closure, nasal penetration, residue in valleculae, coating of pharyngeal wall after swallow fluid, and pharyngeal transit time in the pharyngeal phase. In addition, the treated group showed a significant difference in laryngeal elevation and epiglottic closure, nasal penetration, and pharyngeal transit time in the pharyngeal phase after the treatment compared to the control group. The results of this study showed that neuromuscular electrical stimulation may be an effective method of treating dysphagia in acute phase stroke patients.

Keywords: NMES, VFSS, Dysphagia,

1. INTRODUCTION

Stroke is ranked second highest cause of death in Korea as a single disease [1]. About 15-20% of the stroke patients die after acute phase treatment. Although 10% of stroke patients recover completely, the remaining 70-75% of patients have serious neurologic disorders, depending on the brain regions affected, and chronic dysfunctions in the motor, sensory, cognitive, and speech areas [2]. In particular, about 50% of stroke patients complain of dysphagia when eating and swallowing [3]. Dysphagia due to stroke causes complications such as aspiration pneumonia, airway obstruction, malnutrition, and dehydration. Long-term hospitalization due to delayed functional recovery causes not only economic loss but also decreased quality of life and increased mortality [4]. Most dysphagia patients recover within two months, but in some

cases it may take a few months or even years to recover [5]. If recovery is slow, patients have to use a feeding tube such as percutaneous endoscopic gastrostomy (PEG) in order to maintain normal nutritive conditions.

Treatment for dysphagia includes sensory stimulation to the oral cavity and face, exercise to strengthen the muscles of the oral cavity and throat, neuromuscular electrical stimulation, and surgery [6,7]. Recently, the effect of neuromuscular electrical stimulation (NMES) on the treatment of dysphagia has been reported. Park et al. [8] applied NMES to dysphagia patients through a palatal appliance in order to stimulate the swallowing reflex. After NMES, the patients showed less aspiration and penetration. The total bolus transit time was reduced by 0.28-16.42 seconds, indicating improved swallowing function. In contrast, Power et al. [9] applied NMES to the subjects at the same region as in Park et al.'s study and compared the change in swallowing function with that of a control group. However, this study reported that the treated group showed no improvement in swallowing function. In light of this

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uncertainty, in this study we investigated the effect of NMES using Han et al. [10]'s Functional dysphagia scale (FDS), which is a valid tool for measuring the effect of NMES.

2. SUBJECTS AND METHODS

2.1 Subjects

A total of 28 subjects participated in this study, but eight of these were excluded from the subject group because they were discharged from the hospital and thus unable to complete the four-week electric stimulation treatment during the study period, which was between May and December 2010. Hence, in the end, 20 subjects were included in the subject group. Subjects were neurologically stable stroke patients who were hospitalized at the OO University Hospital in Daejeon. Subject selection was guided by the following conditions: 1) patients had been diagnosed within the past month; 2) patients' dysphagia was verified by the VFSS; and 3) patients had enough cognitive ability to express themselves. Among the patients who satisfied the conditions, we excluded those who had already undergone dysphagia treatment, those to whom a cardiac pacemaker was attached, those who had a severe reflux by parenteral tubing, and those had trauma or inflammation at the electric stimulation application site. Sufficient explanation was given to the subjects regarding the experimental procedures, and written consent indicating voluntary participation was received from the subjects before the experiment. The subjects were evenly distributed in the treated and control groups, to which they were randomly allocated according to hospitalization time. The general characteristics of the subjects were as follows (Table 1).

Table1. The general characteristics of subjects (Mean±SE)

	Treat. (n=10)	Cont. (n=10)	χ^2/Z	P
Sex				
Man	7	6	0.220	0.63
Female	3	4		
Type of stroke				
Hemorrhage	3	2	0.267	1.00
Infarction	7	8		
K-NIHSS ¹⁾	11.30±1.06	11.20±2.20	-0.506	0.63
Age(years)	59.30±6.66	52.60±8.40	-1.480	0.13
Time since onset (months)	2.90±2.44	3.10±3.88	-0.978	0.32
K-MMSE ²⁾	21.20±2.44	21.00±3.88	0.000	1.00

Treat.: Treated group, Cont.: Control group

1. K-NIHSS: Korean version of National Institutes of health stroke scale

2. K-MMSE: Korean-mini mental state exam

2.2 Methods

For both the treated and the control groups, the basic facial stimulation training was conducted for 30 minutes, five times a week, for four weeks. NMES was performed only for the treated group, for 30 minutes each time.

2.2.1 Neuromuscular electrical stimulation (NMES)

NMES was performed only on the treated group, using an electrostimulator (Stim Plus DP-200, Cyber Medic Corp., Iksan, Korea). It was performed for 30 minutes, once a day, five times a week, for four weeks, for a total of 20 times. In two independent channels, pads were placed on both sides of the thyroid notch and two points on the hyoid bone, respectively. The biphasic wave and pulse duration were determined at 80 Hz and 300µsec, respectively, as described in the study of Freed et al. [4]. To prevent laryngeal muscle spasm, electrical stimulation was given intermittently; specifically, a stimulation was given for 50 seconds, before and after which a rise time and a fall time were set for 1 second each, followed by an 8-second pause. The intensity of stimulation was controlled between 3mA and the maximum, depending on the subject's compliance. Inquiries were made as to whether subjects felt inconvenience or pain while undergoing NMES.

2.2.2 Videofluoroscopic swallowing study (VFSS)

VFSS was performed on the two groups by a physical therapist and a resident, who applied the adapted Logemann's method (Logemann, 1998). A semisolid mixture of plain yogurt and 140 g/100 ml of liquid barium was prepared, and the subjects were examined in a lateral sitting position by a videofluoroscope (Philips Omnidagnost, Philips Medical Systems, Eindhoven, Netherlands) while swallowing the mixture three separate times (10 ml per swallow). In the study group, VFSS was performed again after the subjects underwent NMES for four weeks. The video recordings were analyzed at intervals of 0.033 second using the program V1 Home 2.0 (V1 Sports, Plymouth, MI, USA), and the results were evaluated according to the functional dysphagia scale (FDS) presented by Han et al [10].

2.2.3 Functional dysphagia scale (FDS)

The FDS was used in order to evaluate quantitatively oropharyngeal function before and after the experiment. The FDS is a functional scale that represents dysphagia in acute and subacute stroke patients comprehensively and quantitatively, considering the relative odds of aspiration occurrence in the oral phase and pharyngeal phase findings, using the VFSS, which is the standard test for diagnosis of dysphagia. The sensitivity of the scale was 72.0–81.0% and the specificity was 70.7–92.0% out of a full score of 100. The items on the subscale were lip closure (LP), bolus formation (BF), residue in oral cavity (ROC), oral transit time (OTT), triggering of pharyngeal swallow fluid (TPSF), laryngeal elevation and epiglottic closure (LEEC), nasal penetration (NP), residue in valleculae (RV), residue in pyriform sinuses (RPS), coating of pharyngeal wall after swallow fluid (CPWSF), and pharyngeal transit time (PTT) [12].

2.2.4 Statistical methods

All statistical analyses were completed using SPSS 12.0 for Windows. Because of the small sample size, the normality test showed that the normality assumption was not satisfied. Thus, a nonparametric test was performed, setting the significance level at $\alpha=.05$. For the homogeneity test, a χ^2 -test was performed for the categorical data and a Mann-Whitney U test for the continuous data. To compare the effect in each group before and after the measurement, a Wilcoxon signed-ranks test was performed. To compare the effect between the two groups, a Mann-Whitney U test was performed.

3. RESULTS

3.1 Comparison of the FDS before and after the experiment in the treated group and the control group

After the treatment, the FDS of the subject group showed a significant difference in OTT in the oral phase, and in TPSF, LEEC, NP, RV, CPWSF, PTT and total score in the pharyngeal phase ($p<0.05$). The control group showed a significant difference only in the total score (Table 2).

Table 2. The effect of NMES on experimental variables

	Group	Before	After	Z	P
Oral phase					
LC ¹⁾	Treat.	8.00±2.58	6.50±2.40	-1.732	0.08
	Cont.	6.00±2.10	5.50±1.58	-1.000	0.31
BF ²⁾	Treat.	4.50±1.58	3.60±1.26	-1.732	0.08
	Cont.	3.30±2.21	2.70±1.70	-1.414	0.15
ROC ³⁾	Treat.	4.80±1.39	3.80±1.47	-1.890	0.05
	Cont.	3.80±1.98	3.20±1.93	-1.732	0.08
OTT ⁴⁾	Treat.	5.40±1.89	3.00±3.16	-2.000	0.04*
	Cont.	5.40±1.89	4.20±2.89	-1.414	0.15
Pharyngeal phase					
TPSF ⁵⁾	Treat.	8.00±4.21	3.00±4.83	-2.236	0.02*
	Cont.	4.00±5.16	2.00±4.21	-1.414	0.15
LEEC ⁶⁾	Treat.	10.80±3.79	2.40±5.06	-2.646	0.00*
	Cont.	6.00±6.32	4.80±6.19	-1.000	0.31
NP ⁷⁾	Treat.	9.60±2.79	4.40±4.40	-2.565	0.01*
	Cont.	9.20±3.29	8.40±3.50	-1.414	0.15
RV ⁸⁾	Treat.	9.60±2.79	4.80±2.53	-2.585	0.01*
	Cont.	8.00±3.26	6.00±2.82	-1.890	0.05
RPS ⁹⁾	Treat.	6.40±4.69	4.00±4.21	-1.857	0.06
	Cont.	5.20±2.70	4.40±2.27	-1.414	0.15
CPWSF ¹⁰⁾	Treat.	7.00±4.83	3.00±4.83	-2.000	0.04*
	Cont.	5.00±5.27	4.00±5.16	-1.000	0.31
PTT ¹¹⁾	Treat.	2.80±1.93	0.40±1.26	-2.449	0.01*
	Cont.	2.80±1.93	2.40±2.06	-1.000	0.31
Total	Treat.	76.90±16.44	38.40±23.19	-2.803	0.00*

Cont. 58.70±7.42 47.60±7.36 -2.524 0.12*

1. LC: Lip closure, 2. BF: Bolus formation, 3. ROC: Residue in oral cavity, 4. OTT: Oral transit time, 5. TPSF: Triggering of pharyngeal swallow fluid, 6. LEEC: Laryngeal elevation and epiglottic closure, 7. NP: Nasal penetration, 8. RV: Residue in valleculae, 9.RPS: Residue in piriform sinuses, 10. CPWSF: Coating of pharyngeal wall after swallow fluid, 11. PTT : Pharyngeal transit time

Treat. : Treated group, Cont. : Control group

*P<0.05

3.2 Comparison of the Functional Dysphagia Scale before and after the experiment between the treated group and the control group

The treated group showed a significant difference in LEEC, NP, PTT, and total score in the pharyngeal phase compared to the control group (Table 3).

Table3. Effect of NMES on all measurements between groups

	Treat.	Cont.	Z	P
Oral phase				
LC ¹⁾	1.50±2.41	0.50±1.58	-1.090	0.27
BF ²⁾	0.90±1.44	0.60±1.26	-0.503	0.61
ROC ³⁾	1.00±1.41	0.60±0.96	-0.587	0.55
OTT ⁴⁾	2.40±3.09	1.20±2.53	-0.951	0.34
Pharyngeal phase				
TPSF ⁵⁾	5.00±5.27	2.00±4.21	-1.371	0.17
LEEC ⁶⁾	8.40±5.79	1.20±3.79	-2.669	0.00*
NP ⁷⁾	5.20±3.79	0.80±1.68	-2.793	0.00*
RV ⁸⁾	4.80±3.15	2.00±2.82	-1.934	0.05
RPS ⁹⁾	2.40±3.37	0.80±1.68	-1.125	0.26
CPWSF ¹⁰⁾	4.00±5.16	1.00±3.16	-1.510	0.13
PTT ¹¹⁾	2.40±2.06	0.40±1.26	-2.285	0.02*
Total	38.00±27.28	11.10±8.66	-1.968	0.04*

1. LC: Lip closure, 2. BF: Bolus formation, 3. ROC: Residue in oral cavity, 4. OTT: Oral transit time, 5. TPSF: Triggering of pharyngeal swallow fluid, 6. LEEC: Laryngeal elevation and epiglottic closure, 7. NP: Nasal penetration, 8. RV: Residue in valleculae, 9.RPS: Residue in piriform sinuses, 10. CPWSF: Coating of pharyngeal wall after swallow fluid, 11. PTT : Pharyngeal transit time

Treat. : Treated group, Cont. : Control group

*P<0.05

4. DISCUSSION

The evaluation and treatment of dysphagia are important for stroke patients to achieve independence in society through independent daily living [12]. In the past, various methods based on different mechanisms have been suggested and applied to treat dysphagia in stroke patients and improve their swallowing function. However, conventional treatment methods such as posture technique or temperature and tactile stimulation had unclear effects and failed to provide basic treatment. In this study, therefore, we directly applied NMES to the neck muscle for the treatment of post-stroke dysphagia and verified the effects using the FDS. Of the various tests to evaluate swallowing function, the videofluoroscopic swallowing study (VFSS) has been found to be the most valid and reliable method. Generally, the VFSS is a qualitative examination based on the findings of a doctor who watches a video. However, Han et al. [10] quantified the video reading findings by developing the functional dysphagia scale.

The NMES treatment, developed by Freed et al.[4] is a method that trains the nerves and muscles to function through electric stimulations. The type of electricity used is different from that of the low-frequency therapeutic apparatus that is used to treat peripheral neuropathy. In Freed et al.'s [4] method, the minutely regulated electric current is applied through an efficiently designed electrode to stimulate the motor nerves of the neck. As the muscles relevant to swallowing function react to the stimulation, the quality of swallowing function is improved and the muscles are re-trained through repeated treatment.

The application of NMES to the treatment of dysphagia is increasing as recent studies have shown that NMES is effective for the improvement of swallowing function in patients with post-stroke dysphagia [4, 12]. The advantage of NMES is that the effects can be seen within a short period of time, the application is easy, and the treatment can be performed at home after some training

NMES for dysphagia can improve the symptoms since it strengthens the laryngopharyngeus muscle involved in swallowing, enhances the swallowing reflex by reactivating the nervous pathway in the oral cavity, and supports the thyrohyoid muscle that lifts up the larynx and the thyroarytenoid muscle that adducts the glottis. It provides this support simultaneously contracting the mylohyoid muscle that lifts up the larynx, the geniohyoid muscle, the stylohyoid muscle, and the surrounding muscles to reduce the distance between the hyoid bone and the thyroid cartilage [4, 6, 12].

In our study, after four weeks of treatment, the FDS of the treated group showed a significant difference in OTT in the oral phase and in TPSF, LEEC, NP, RV, CPWSF, and PTT in the pharyngeal phase. Additionally, the treated group showed a significant difference in LEEC, NP, and PTT in the pharyngeal phase after treatment when compared to the control group.

The FDS showed that the improvement in swallowing function was more distinctive in the pharyngeal phase than in the oral phase, which is consistent with Yoon et al.'s[13] results. The functions of the muscles involved in the pharyngeal phase might have improved more because the electrodes were attached at both sides, such that the digastric muscle and the thyroid cartilage were at the center, and the electric stimulation was applied to the thyrohyoid muscle.

The muscle-strengthening mechanism of NMES has not been clearly investigated. Nonetheless, we have found that NMES may induce muscle strengthening by increasing the mass of the muscles through a program that includes highly intensive muscular contractions and low-level repetition, which has effects similar to those of physical exercise. Secondly, in contrast to normal muscle recruitment order, functional electric stimulation might have increased the contracting power of the muscles by preferentially recruiting the Type II muscular fiber, which has greater power than Type I muscular fiber [13]. Considering that the four weeks of treatment in this study was a relatively short period, the improvement of muscular function relevant to swallowing might have been due to an improved ability to selectively recruit the Type II muscular fiber rather than an effect of increased muscular mass.

In study of Power et al. [9], no change was observed in the speed of laryngeal elevation, pharyngeal transit time, or aspiration severity within subjects. I thought that the recovery of the subjects were delayed because the subject's age was 73 ± 0.07 years and the time since onset was longer than subjects from my experiment.

In light of the results of our study, functional electric stimulation may be an effective method to treat dysphagia in acute-phase stroke patients. However, this study has many limitations and we must use caution in generalizing these results, since the study was conducted for only four weeks. Thus, long-term follow-up studies may be necessary in the future.

5. CONCLUSION

NMES was implemented for 30 minutes, once a day, 5 times a week, for 4 weeks, with 20 acute phase stroke patients having dysphagia to verify the therapeutic effect, and the result showed that there was a significant improvement in LEEC, NP and PTT in the pharyngeal phase ($P < 0.05$). Therefore, it is assumed that the NMES may help improve the swallowing function of acute phase stroke patients.

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