Dysphagia after stroke is associated with mortality and increased pulmonary complications. Swallowing therapies may decrease pulmonary complications and improve patients’ quality of life after stroke. This study used clinical swallowing assessments and videofluoroscopy (VFS) to assess the functional recovery of acute stroke patients with dysphagia after different swallowing therapies. We enrolled 29 acute stroke patients with dysphagia and randomly divided them into 3 therapy groups: traditional swallowing (TS), oropharyngeal neuromuscular electrical stimulation (NMES), and combined NMES/TS. All patients were assessed using the clinical functional oral intake scale (FOIS), 8-point penetration–aspiration scale (PAS), and functional dysphagia scale (FDS) of VFS before and after treatment. There were no differences in the clinical parameters and swallowing results of the FOIS and VFS before swallowing treatment among the 3 groups (P > .05). TS therapy and combined therapy both had significant swallowing improvement after therapy according to the FOIS and 8-point PAS (P < .05). When comparing the results of the VFS among the 3 groups, we found significant improvements in patients eating cookies and thick liquid after combined NMES/TS therapy (P < .05). In acute stroke patients with dysphagia, combined NMES/TS therapy is the most effective swallowing therapy in taking solid diets and thick liquids. Key Words: Dysphagia—stroke—neuromuscular electrical stimulation—swallowing therapy—videofluoroscopy.

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Introduction

Dysphagia is one of the most common morbidities after stroke, with a reported incidence of 29%-81%. Dysphagia after stroke is associated with mortality and increased pulmonary complications, and mortality, all of which lead to a poor prognosis. Poststroke dysphagia increases the risk for dehydration, malnutrition, pulmonary complications, and mortality, all of which lead to a poor prognosis. Poststroke dysphagia increases the risk for dehydration, malnutrition, pulmonary complications, and mortality, all of which lead to a poor prognosis. For patients with poststroke dysphagia, aspiration pneumonia occurs in 43%-50% of patients during the first year, with a mortality of up to 45%. Additionally, it is associated with increased long-term institutionalization. Some patients with severe dysphagia require a percutaneous feeding tube for nonoral feeding to sustain adequate nutrition and/or water intake. However percutaneous feeding tube such as nasogatric tube
provided limited protection against aspiration-associated pneumonia in poststroke patients with dysphagia. The enteral feeding tubes also cause nasopharyngeal discomfort, impairs the patients’ body image, and affects their quality of life. Therefore, early diagnosis and intervention for poststroke dysphagia is important and recommended to prevent stroke-associated pneumonia.

There are several practical methods for decreasing complications associated with dysphagia, including postural adjustments, viscosity changes to food and liquids, oropharyngeal exercises, swallowing maneuvers, thermal stimulation, and enteral feeding, to manage swallowing dysfunction. Traditional swallowing (TS) therapy involves compensation strategies, such as postural adjustment or diet modification, strengthening weak oropharyngeal musculature through oral exercise, swallowing maneuvers for the augment impaired aspects of oropharyngeal swallowing, and heightening sensory input through thermal–tactile stimulation. Severe poststroke dysphagia is more likely to develop aspiration pneumonia or other potentially complications during prolonged treatment. However, effective swallowing therapies are limited for stroke patients with severe dysphagia, which requires long-term treatment.

Recently, neuromuscular electrical stimulation (NMES) has become a possible intervention for restoring swallowing function. The VitalStim (Chattanooga Group, Hixson, TN) therapy is a type of transcutaneous NMES, which was approved by the Food and Drug Administration in 2001 for treatment of dysphagia. This therapy bypasses the injured central swallowing circuitries such as stroke and delivers an electrical current via electrodes that are placed on the neck muscles to create a contraction of the swallowing muscles. NMES may create more laryngeal elevation and increase the strength of the associated muscles, which leads to better swallowing motion in dysphagic patients. Bulow et al reported positive therapy effects for both NMES and TS therapy combined on more than 3 months hemispheric stroke patients with oral and pharyngeal dysfunction. Kushner et al presented that NMES with traditional dysphagia therapy/progressive resistance training is significantly more effective than traditional dysphagia therapy/progressive resistance training only for reducing tube-dependent dysphagia in acute stroke patient. However, there is still a lack of more objective evidence about the efficacy of NMES for treating poststroke dysphagia at acute phase.

We aimed to evaluate the functional recovery in acute stroke patients with oropharyngeal dysphagia after TS, oropharyngeal NMES, and combined NMES/TS, by using clinical swallowing assessments and objective video-fluoroscopy (VFS).

Materials and Methods

Participants

Between January 2011 and July 2013, we enrolled 29 acute stroke patients with dysphagia (20 men, 9 women) who were admitted to a rehabilitation unit of the Chang Gung Memorial Hospital-Kaohsiung Medical Center in Taiwan. All the patients’ strokes occurred less than 3 months before enrollment (mean, 22.4 days; range, 5-50 days). The strokes were diagnosed by neurologists according to the clinical neurologic deficits relating to their brain damage and the findings on brain computed tomography or magnetic resonance imaging scans. Their swallowing disorders were impressed by physiatrists taking the history of choking or cough during swallowing or wet voice after conducting a 100-mL water test. Furthermore, a formal swallowing condition was assessed by 1 speech–language therapist.

The inclusion criteria were recent cerebral hemispheric stroke with swallowing difficulty with functional oral intake scale (FOIS), which was equal to or less than level 4 while admission to the rehabilitation unit. The exclusion criteria were as follows: (1) impaired communication ability due to cognitive deficit, aphasia, or serious psychologic disorders; (2) other systemic neurologic disorders leading to swallowing difficulty; (3) swallowing disorders caused by structural lesions, such as an oropharyngeal tumor or extensive surgery or radiotherapy of the head and neck region; (4) use of an electrically sensitive biomedical device (eg, cardiac pacemaker); and (5) pneumonia or acute medical conditions at the time of enrollment. The study was reviewed by the institutional ethics committee at our hospital, and after understanding of all procedures in this study, informed consent was obtained from each patient.

Procedures

Clinical parameters, including age, gender, stroke type, stroke location, duration since stroke onset, the Mini-Mental State Examination (MMSE), and the National Institute of Health Stroke Scale (NIHSS), were recorded when the participants were admitted to our rehabilitation unit. We randomly divided the patients into 3 groups. There were 11 patients in the TS group, 8 patients in the NMES group, and 10 patients in the combined NMES/TS group.

In the TS group, the therapies included oral exercise, compensatory techniques (eg, chin tuck, head tilt, and head rotation), faucial thermal–tactile stimulation, and swallowing therapeutic maneuvers (eg, supraglottic swallowing, effortful swallowing, and the Mendelsohn maneuver). These dysphagia therapies are commonly used in rehabilitation departments. The TS therapies were performed by 1 qualified and experienced speech–language therapist. The choice of specific and compensatory
techniques and swallowing maneuvers was based on the findings of VFS and the clinical evaluation of swallowing. This group of patients was treated 3 times per week (60 minutes per treatment), and 10 sessions were performed for each patient.

In the NMES group, we used the VitalStim therapeutic device, which consists of a dual channel with 2 bipolar electrodes for each channel. The parameters of electrical stimulator are a pulse width of 700 μs, frequency of 80 Hz, and wave amplitude of 0-25 mA. A licensed physiatrist with 10 years of clinical experience and certified training in using the VitalStim electrical stimulator administered the NMES. Each patient’s anterior neck skin was cleaned using an alcohol swab to remove substances that might interfere with the electrode contact, and the 2 sets of electrodes were placed on the patients’ anterior neck. The placement of the dual-channel electrodes was located in 1 vertical line with channel 1 above the thyroid notch and channel 2 below the thyroid notch. The wave amplitude of the treatment was set according to the patient’s tolerance level, and it gradually increased in a stepwise increment of 0.5 mA from 0 mA until the patient felt a tingling sensation on the neck and a muscle contraction. The tolerance wave amplitude was different among individuals. The current intensity of the electrical stimulation was determined and fixed during the treatment session. Patients were not instructed to perform any oropharyngeal exercises or swallowing training during NMES treatment. These patients were treated 3 times per week (60 minutes per session), and 10 sessions of NMES were performed per patient.

In the combined NMES/TS group, another licensed physiatrist with experienced and certified training in using the VitalStim device administered the therapy. These participants accepted combined TS therapies from the same physiatrist while receiving NMES therapy. The treatment occurred 3 times per week (60 minutes per treatment), and each patient had 10 sessions.

Outcome Measurement

Three quantifiable methods were used to evaluate the swallowing function before and after treatment. The FOIS was reported by Crary et al for assessing the oral intake of food and liquid in stroke patients. The FOIS is a statistically validated scale that reflects the functional oral intake of poststroke patients with dysphagia. An ordinal series of 7 swallowing function levels was used (1-7). The level ranged from nothing by mouth (level 1) to total oral diet with no restriction (level 7). One speech–language therapist who was blinded to all procedures evaluated the FOIS for each patient before and after swallowing treatments.

The VFS is a standard tool for observation and identification of swallowing abnormalities. The 8-point penetration–aspiration scale (PAS) and functional dysphagia scale (FDS) based on VFS provided a quantitative and objective measurement for swallowing disorders. The 8-point PAS describes the severity of respiration compromise and is a validated and reliable index of aspiration. Penetration was defined as any material entering the laryngeal vestibule but remaining at or above the vocal folds. Aspiration was defined as any material entering the larynx below the vocal folds. In the 8-point PAS, the scores ranged from normal swallowing without material entering the airway (score 1) to severe airway compromise with material entering the airway and passing below the vocal folds (score 8). The 11-item FDS reported by Han et al in 2001 is a sensitive and specific method for quantifying swallowing function in stroke patient. The FDS is composed of 11 items that quantitatively measure oral function (lip closure, bolus formation, residual in oral cavity, and oral transit time) and pharyngeal function (triggering of pharyngeal swallowing, laryngeal elevation and epiglottis closure, nasal penetration, triggering, residue in valleculae and pyriform sinus, pharyngeal coating, and pharyngeal transit time) during VFS. A total 100 points was scored according to the findings of VFS. The lower the FDS score, the better swallowing function. The FDS was measured during 4 diets (soft diet, cookies, thick liquid, and thin liquid). Both the 8-point PAS and FDS were interpreted and scored before and after each therapy by another well-experienced speech–language therapist who was also blinded to all 3 interventions.

Data Analysis

SPSS software, version 12.0 (SPSS, Chicago, IL) was used to analyze all collected data. The Kruskal–Wallis test was used to compare differences in age, MMSE, NIHSS among the TS, NMES, and combined NMES/TS groups at admission. The differences in gender, stroke type, and stroke location among the TS, NMES, and combined NMES/TS groups at admission were calculated using χ² test. The FOIS, FDS, and 8-point PAS scales were assessed among the 3 groups before and after treatment and were compared using the Kruskal–Wallis test. The statistical significance was set as P < .05.

Results

Twenty-nine acute stroke patients with dysphagia were included in this study. All clinical parameters are shown in Table 1. Eleven patients were in the TS group (5 women and 6 men; median age, 67.0 years), 8 patients were in the NMES group (3 women and 5 men; median age, 64.5 years), and 10 patients were in the combined NMES/TS group (1 woman and 9 men; median age, 68.9 years). There were no significant differences in age, gender, stroke type, NIHSS, MMSE, and stroke duration among the 3 groups. In the TS group, there were 6 patients (55%) without oral intake (FOIS, 1) and 5 patients...
Three patients (38%) with FOIS 1 and 5 patients (62%) with FOIS 2-4 were in the NMES group. Five patients (50%) with FOIS 1 and 5 patients (50%) with FOIS 2-4 were in the combined NMES/TS group. No significant difference was noted in FOIS subgroup among these 3 groups.

The median FDS during VFS before therapy while on a soft diet, cookies, and thick and thin liquid were 21.1, 19.2, 26, and 18.9 in the TS group, 11.4, 17.8, 18.9, and 12.4 in the NMES group, and 25.4, 30, 32.6, and 22.3 in the combined NMES/TS group, respectively (Table 2). The median 8-point PAS during VFS in the TS, NMES, and combined NMES/TS groups were 3.8, 3.0, and 3.5, respectively. The median FOIS in the TS, NMES, and combined NMES/TS groups were 1.6, 2.3, and 1.8, respectively.

There were no statistically significant differences in the swallowing evaluations, including the median FOIS, 8-point PAS, and FDS during VFS, among the 3 groups before therapy. The median FDS scales while on a soft diet, cookies, and thick and thin liquid were 21.1, 19.2, 26, and 18.9 before treatment and 15.7, 24.8, 23.4, and 16.2 after treatment in the TS group, respectively. The median FDS scales in the 4 kinds of diet were 11.4, 17.8, 18.9, and 12.4 before treatment and 18.3, 22.5, 22.6, and 11.9 after treatment in the NMES group, respectively. The median FDS scales while on a soft diet, cookies, and thick and thin liquid were 25.4, 30, 32.6, and 22.3 before treatment and 16.4, 10.6, 24.7, and 16.8 after treatment in the combined NMES/TS group, respectively. In the TS group, the median 8-point PAS scales were 3.8 and 2.4, and the median FOIS scales were 1.6 and 4.6 before and after treatment, respectively. In the combined NMES/TS group, the median 8-point PAS were 3.5 and 2.5, and the median FOIS were 1.8 and 5.5 before and after therapy, respectively. There were significant differences in FOIS before and after therapy in all 3 groups (P < .05). There were significant differences in the PAS before and after therapy in TS and combined NMES/TS groups (P < .05). Significant differences were found between the median FDS before and after therapy while on a soft diet in the combined NMES/TS group (P < .01).

In Table 3, the change of FDS during VFS after therapy while on a soft diet, cookies, and thick and thin liquid were −5.4, 7.6, −2.6, and −2.7 in the TS group, 6.9, 4.8, 3.8, and −5 in the NMES group, and −9.0, −16.3, −7.9, and −5.5 in the combined NMES/TS group, respectively. Significant differences were found in the changes of FDS while on a cookie (P < .03) and thick liquid (P < .04) after treatment among the 3 groups. There were no significant differences in the changes of FDS while on a soft diet and thin liquid after therapy among the 3 groups (P > .05). The changes of the 8-point PAS after intervention were −1.5, −1.3, and −1.0 in the TS, NMES, and combined NMES/TS groups, respectively. The changes of the FOIS were 3.0, 2.6, and 3.7 in the TS, NMES, and combined NMES/TS groups, respectively. No significant differences were found in the changes of the 8-point PAS and FOIS among the 3 groups (P > .05).

Discussion

We are the first in this field to investigate the effect of NMES, TS therapy, and combined NMES and TS therapy in acute stroke with oropharyngeal dysphagia by both FOIS and VFS with 8-point PAS and FDS. The results in this study showed that TS, NMES, and combined...
NMES/TS therapy had a significant improvement on the clinical FOIS score and TS, and combined NMES/TS therapy had a significant improvement on the 8-point PAS during VFS. However, no statistically significant differences were found among these 3 therapies. In the NMES therapy, we also found an improvement tendency after treatment on 8-point PAS, but it was not statistically significant. The study indicated that all 3 treatments might provide some positive therapeutic effects for acute stroke patients with dysphagia. The results were consistent with previous studies in chronic stroke. Bulow et al.\(^2\) reported statistically significant positive effects for both NMES and TS therapy in chronic stroke patients with dysphagia, but there was no statistically significant difference in therapy effect between the groups.

We demonstrated that a combined NMES/TS therapy could result in better swallowing performance in FDS scores than NMES or TS therapy alone while on cookies and thick liquid during VFS. In the combined therapy group, we also found a tendency for the FDS to improve while on soft diet or thin liquid, but the difference before and after therapy was not statistically significant. This result is similar to that of previous studies. Lim et al.\(^3\) reported that NMES combined with thermal–tactile stimulation is a better treatment for patients with swallowing disorders after stroke than thermal-tactile stimulation alone. Kushner et al.\(^4\) found significant improvement in FOIS in the NMES group with traditional dysphagia therapy/progressive resistance training; therefore, they suggest that this combined therapy is more effective than traditional dysphagia therapy/progressive resistance training only for reducing tube-dependent dysphagia in acute stroke patients. The application of NMES for dysphagia associated with oropharyngeal dysfunction is for improving sensation input of oropharyngeal cavity, facilitating or restoring the oral or pharyngeal motor function, and achieving adequate laryngeal elevation. Therefore, concurrent NMES could further augment or enhance the contraction of paralyzed oropharyngeal muscles with volitional control. Although the TS therapy is a mainstay for the management of dysphagia after stroke by strengthening the weakened oropharyngeal muscles under voluntary oral or swallowing exercise, these findings supported that NMES could be used as an alternative therapy for acute stroke patients with dysphagia.

We consider that NMES can be an adjunctive therapy to the general swallowing therapy. First, with moderate-to-severe dysphagia, there is little or no muscle contraction of oropharyngeal muscles under voluntary swallowing action. The NMES can avoid the disuse of muscle dystrophy and strengthen contraction of paralyzed oropharyngeal muscles. Second, the order of the muscle recruitment of voluntary muscle contraction and that of electrical stimulation are different. During normal muscle contraction, the type I muscle fibers are recruited first and followed by the recruitment of type II muscle fibers. The recruitment of

<table>
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<tr>
<th>Group</th>
<th>Before treatment</th>
<th>After treatment</th>
<th>P value</th>
<th>Before treatment</th>
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<th>P value</th>
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<th>After treatment</th>
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<tbody>
<tr>
<td>TS group, N = 11</td>
<td>FDS</td>
<td>Soft diet, median (IQR)</td>
<td>21.1 (14.9)</td>
<td>15.7 (13.5)</td>
<td>.14</td>
<td>11.4 (8.4)</td>
<td>.06</td>
<td>25.4 (13.0)</td>
<td>16.4 (17.6)</td>
<td>.06</td>
<td>16.8 (13.6)</td>
<td>25.4 (13.0)</td>
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<td></td>
<td>Cookie, median (IQR)</td>
<td>19.2 (18.0)</td>
<td>24.8 (11.7)</td>
<td>.16</td>
<td>17.8 (7.0)</td>
<td>.08</td>
<td>22.5 (9.3)</td>
<td>30.0 (17.0)</td>
<td>.08</td>
<td>22.5 (9.3)</td>
<td>28.6 (11.9)</td>
<td>.08</td>
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<td></td>
<td>Thick liquid, median (IQR)</td>
<td>26.0 (13.5)</td>
<td>23.4 (10.0)</td>
<td>.26</td>
<td>18.9 (3.0)</td>
<td>.05</td>
<td>22.6 (8.1)</td>
<td>32.6 (11.9)</td>
<td>.05</td>
<td>22.6 (8.1)</td>
<td>32.6 (11.9)</td>
<td>.05</td>
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<td></td>
<td>Thin liquid, median (IQR)</td>
<td>3.8 (2.6)</td>
<td>2.4 (1.4)</td>
<td>.04</td>
<td>2.5 (1.4)</td>
<td>.01</td>
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<tr>
<td>NMES group, N = 8</td>
<td>FOIS, functional oral intake scale</td>
<td>3.8 (2.6)</td>
<td>3.8 (2.6)</td>
<td>.04</td>
<td>3.2 (2.6)</td>
<td>.03</td>
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<td>3.8 (2.6)</td>
<td>.03</td>
<td>3.8 (2.6)</td>
<td>3.8 (2.6)</td>
<td>.03</td>
</tr>
<tr>
<td>Combined NMES/TS group, N = 10</td>
<td>8-point PAS, median (IQR)</td>
<td>1.6 (8.8)</td>
<td>1.6 (8.8)</td>
<td>.04</td>
<td>2.3 (4.2)</td>
<td>.01</td>
<td>1.6 (8.8)</td>
<td>2.3 (4.2)</td>
<td>.01</td>
<td>1.6 (8.8)</td>
<td>2.3 (4.2)</td>
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Abbreviations: IQR, interquartile range; FDS, functional dysphagia scale; FOIS, functional oral intake scale; NMES, neuromuscular electrical stimulation; PAS, penetration–aspiration scale; TS, traditional swallowing.

Table 2. Videofluoroscopy and FOIS results in TS, NMES, and combined NMES/TS groups before and after therapy
NMES, reverse of normal voluntary recruitment, involves type II fibers first followed by slow type I fibers. 25,36 The synchronous recruitment of both types I and II muscle fibers during combined therapy can generate larger swallowing muscle force and enhance the therapeutic effect than NMES or TS exercise alone in dysphagia treatment. Third, the electrical stimulation combined with swallowing task training and exercise can increase swallowing excitability and facilitate motor learning. Park et al 37 reported that effortful swallowing coupled with electrical stimulation increased the degree of hyoid elevation in healthy volunteers. Ludlow et al 38 observed that hyoid bone depression occurred with stimulation at rest, and stimulation may have acted to resist the patient’s hyoid elevation during swallowing. Fourth, the NMES can heighten the pharyngeal sensory feedback pathway and stimulate pharyngeal cortical reorganization. Oh et al 21 reported that multiple sessions of electrical stimulation applied to the neck muscles improve swallowing function via a mechanism involving long-term cortical reorganization measured by corticobulbar output maps, which suggests that multiple sessions of electrical stimulation applied to the neck muscles improve swallowing function via a mechanism involving long-term cortical reorganization. However, the exact mechanism of NMES remains unclear. Further study is needed to investigate the possible cortical mechanism of NMES on poststroke dysphagic patients.

The following are the several limitations to our study: (1) we collected a small patient group limited to 1 rehabilitation unit in 1 medical center in Taiwan, which may impede smaller significant differences among groups; (2) because of an ethical issue, we did not have stroke patients with dysphagia receive any treatment in a control group to exclude the effect of a spontaneous recovery of a swallowing deficit; (3) there was no standard NMES therapy protocol for the current intensity, frequency, the duration of the intervention; and (4) there was a lack of long-term follow-up to assess the swallowing function recovery after completing the 3-week therapy.

In summary, TS therapy and combined therapy both have therapeutic effects on improving the swallowing function based on the clinical FOIS and 8-point PAS during VFS in acute stroke patients with dysphagia. However, among the 3 therapies, the combined NMES with TS therapy may result in more positive effects, because it showed a significant improvement in FDS when the patients were on a solid diet and thick liquid during VFS.

### References