Therapeutic efficacy of neuromuscular electrical stimulation and electromyographic biofeedback on Alzheimer’s disease patients with dysphagia

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Abstract
To study the therapeutic effect of neuromuscular electrical stimulation and electromyographic biofeedback (EMG-biofeedback) therapy in improving swallowing function of Alzheimer’s disease patients with dysphagia.

A series of 103 Alzheimer’s disease patients with dysphagia were divided into 2 groups, among which the control group (n=50) received swallowing function training and the treatment group (n=53) received neuromuscular electrical stimulation plus EMG-biofeedback therapy. The mini-mental state scale score was performed in all patients along the treatment period. Twelve weeks after the treatment, the swallowing function was assessed by the water swallow test. The nutritional status was evaluated by Mini Nutritional Assessment (MNA) as well as the levels of hemoglobin and serum albumin. The frequency and course of aspiration pneumonia were also recorded.

No significant difference on mini-mental state scale score was noted between 2 groups. More improvement of swallowing function, better nutritional status, and less frequency and shorter course of aspiration pneumonia were presented in treatment group when compared with the control group.

Neuromuscular electrical stimulation and EMG-biofeedback treatment can improve swallowing function in patients with Alzheimer’s disease and significantly reduce the incidence of adverse outcomes. Thus, they should be promoted in clinical practice.

Abbreviations: AD = Alzheimer’s disease, ALB = serum albumin, DSM-IV = Diagnostic and Statistical Manual of Mental Disorders, 4th ed, EMG-biofeedback = electromyographic biofeedback, Hb = hemoglobin, MMSE = Mini-mental state examination, MNA = Mini Nutritional Assessment, NINCDS-ADRDA = National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer’s Disease and Related Disorders Association, NMES = neuromuscular electrical stimulation, WST = water swallow test.

Keywords: Alzheimer’s disease, dysphagia, electromyographic biofeedback, neuromuscular electrical stimulation, rehabilitation

1. Introduction
Swallowing dysfunction is a common clinical presentation in patients with Alzheimer’s disease (AD) in the medium and long term. It was estimated that 80% of these patients would suffer from oropharyngeal dysphagia if left untreated. In advanced stages, the incidence of dysphagia can increase up to 93%. Dysphagia is frequently associated with malnutrition, dehydration, and aspiration pneumonia. Causing severe consequences of the quality of life. Therefore, it is of great importance to seek for effective treatments for dysphagia.

Neuromuscular electrical stimulation (NMES) was proposed as a therapeutic adjunct in the treatment of dysphagia.[6–9] By stimulating the nerve as well as the motor end-plate, NMES can be used for remodeling the functional muscle contraction patterns[10] and thus improve the swallowing function. On the other hand, electromyographic biofeedback (EMG-biofeedback) has been advocated as an adjunct to swallowing therapy with prior reports of rapid progress in patients treated with this approach, even in chronic patients.[11–13] Also, it was suggested to be effective in patients with pharyngeal dysphagia after stroke.[12,13] However, the effect of NMES and EMG-biofeedback in treating AD patients with dysphagia has not been well elucidated.

In this study, combination therapy with the NMES and EMG-biofeedback was adopted to explore effective treatment for swallowing disorder in AD patients with dysphagia.

2. Materials and methods
This study was approved by Ethics Review Board of Fujian Provincial Geriatric Hospital. Forms of written consent were obtained from all to patients involved in this study.

2.1. Participants
A series of 103 AD patients with dysphagia, who were treated in neurological department of Fujian Provincial Geriatric Hospital from March 2013 to November 2016, were included in this study. After reviewing the medical records, patients were retrospectively divided into 2 groups according to the treatment they underwent. The patients treated with swallowing function...
training, which is a basic treatment, were enrolled in control group. In addition to swallowing function training, combination treatment with NMES and EMG-biofeedback was conducted in treatment group. Patient in control group refused further treatment with NMES and EMG-biofeedback due to the personal concerns instead of medical considerations. The control group consisted of 50 patients (30 men) with a mean age of 76.2±2.3 while the treatment group included 53 patients (26 men) with a mean age of 72.5±2.5.

For the diagnosis of dysphagia, videofluoroscopic swallowing assessment with the scoring criteria described by the previous literature was adopted. The standard method of videofluoroscopic swallowing assessment was as described by Verin et al. Since this study was conducted in AD patients, those who complained of dysphagia but did not show any abnormal findings in videofluoroscopic swallowing assessment were not included in this study.

For the diagnosis of AD, there were a set of inclusion and exclusion criteria adopted in our department. Patients were diagnosed with AD according to the Diagnostic and Statistical Manual of Mental Disorders, 4th ed (DSM-IV) and National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer’s Disease and Related Disorders Association (NINCDS ADRA) criteria. Patients with the following conditions were excluded: pseudo dementia (such as depressive dementia), mental retardation, low cognitive function due to extreme poverty and limited education or drug-induced intelligence damage. The dementia syndrome caused by liver failure, pernicious anemia, reduced thyroid function or hyperthyroidism, neuro syphilis, prion diseases, or AIDS were ruled out by related serological tests.

2.2. Clinical assessments and functional assessment of dysphagia

Physical examinations including general, neurological, and dental examinations as well as routine blood tests were performed on admission. The levels of hemoglobin (Hb) and serum albumin (ALB) were viewed as adjunct indicator of nutritional status. Mini Nutritional Assessment (MNA) was performed by 2 trained nutritionists to evaluate the nutritional status of all the patients involved. The MNA consisted of 6 questions on food intake, weight lose, mobility, psychological stress or acute disease, neuropsychological problems, and body mass index or calf circumference. These 6 items yield 0 to 2 or 0 to 3 points, with 0 indicating poor function and 2 or 3 indicating normal function. Scores from 12 to 14 points implicate normal nutritional status, patients with scores from 8 to 11 points are at risk of malnutrition, and those with 0 to 7 points are considered as malnourished.

Mini-mental state examination (MMSE) was used to determine the normal cognitive function in healthy controls by the following decisive criteria: the points achieved by the subjects were greater than the highest mark of the corresponding literacy level (illiteracy >17 points, primary school >20 points, more than high school >24 points).

Water swallow test (WST) were also conducted in all patients to evaluate the swallowing function before and after treatment. Patients were asked to drink 30mL tepid water and the scores were given accordingly as shown in Table 1. The pretreatment score was indicated as N0 and posttreatment score as N1 (12 weeks later). The difference between N0 and N1 was defined as N (N=N0−N1). The effect of treatment was interpreted as deteriorated, ineffective, effective, and excellent when N was <0, 0, 1, and >1, respectively.

2.3. Rehabilitation therapy

The rehabilitation therapy was performed in each patient according to a routine rehabilitation training described in a previous reported, including tongue exercises, pharynx and larynx exercises. Each exercise in rehabilitation therapy was repeatedly practiced for 15 circles at each time for a total of 45 circles per day.

2.4. NMES and EMG-biofeedback

Aside from the swallowing function training, NMES and EMG-biofeedback were also conducted in the treatment group. Patients were comfortably seated in a reclining chair with skin electrode attached. Electrical stimulation was delivered using a dual-channel electrotherapy system of VitalStim (Chatanooga Group, Hixson, TN). The thyroid notch was identified by palpation and the first electrode was placed midline 1 mm above it, the second electrode immediately superior to the first electrode, the third electrode 1 mm below the thyroid notch, and the fourth electrode immediately inferior to the third electrode. NMES was applied at a frequency of 80 Hz with a wave width of 700 μs and wave amplitude 0 to 2.5 mA. The stimulus intensity was gradually increased in 0.5 mA increments until patients reported feeling a “grabbing” sensation, which was demonstrated in patients in the pretreatment to be identified. The amplitude of the electrical current was regulated according to the patients’ verbal feedback and when a grabbing sensation was reported, the amplitude was left at that level for the remainder of the 60-minutes therapy session.

The swallowing activity was visualized with the application of EMG (MyeTrac III, Thought Technology, Canada) of the submental muscle and the data were recorded on a computer. Electrodes were placed on the submental region, which was between the mandible and the hyoid, to record the muscle activity of submental muscle (musculi stylohyoideus, musculi mylohyoideus, musculi digastricus). In the treatment of dysphagia with EMG-biofeedback, patients were instructed to make Mendelsohn maneuver, where they prolonged the laryngeal excursion to the maximum of 2 to 3 seconds. The EMG signal was on a computer monitor and patients had an immediate feedback of their swallowing action. NMES and EMG-biofeedback were conducted once a day with 1 hour at a time.

All the patients in treatment group and control group were exercised and evaluated by the same therapist. Data were collected on an outpatient basis about every 4 weeks (W0, W4, W8, W12), including the evaluation of swallowing function, the

| Table 1 Descriptions of scoring system in water swallow test. |
|-------------|
| Score | Description |
| 1 | Patient was able to drink 30mL water within 5 s at 1 time without coughing or pause |
| 2 | Patient was able to drink the water at 1 time and required more than 5 s, or to finish drinking at twice without cough or a pause |
| 3 | Patient was able to drink the water at 1 time with choking |
| 4 | Patient was able to finish drinking at twice with choking |
| 5 | Patient was choked and not able to drink the water |
levels of Hb and ALB, the results of MNA and MMSE. Meanwhile, the reported incidences of aspiration pneumonia in the 2 groups during follow-up were also recorded.

2.5. Statistical methods

SPSS13.0 software package (Chicago, IL) was used for statistical analysis. Statistical data were expressed as mean ± standard deviation and \( P < .05 \) was considered statistically significant. Comparisons of the results of MMSE, MNA, and WST, the level of Hb and ALB were made with the use of t test while demographic data were analyzed by the Pearson \( x^2 \) test. The comparison of the results of WST was made with the use of Mann–Whitney U test.

3. Results

No statistically significant difference on sex, age, the results of MMSE, MNA, and WST, the level of Hb and ALB between the 2 groups was observed on admission (Table 2).

Along the whole treatment periods, no significant difference on MMSE was presented between 2 groups (\( P < .05 \)). After 12 weeks of treatment, improvement of swallowing function assessed by WST was noted in both groups while more improvement was noted in treatment group than that in control group (\( P < .05 \)) (Tables 3 and 4). The nutritional status, evaluated by MNA and the levels of Hb and ALB, was better achieved in treatment when compared with control group after 12 weeks of treatment (\( P < .05 \)) (Table 4). As for the complication of aspiration pneumonia, less frequency and shorter course was presented in treatment group when compared with control group (Fig. 1).

4. Discussion

The reflex center of swallowing is located in the brain stem, while the start of swallowing action depends on the cortex motor area and the integrity of limbic cortex. Quite a few studies have

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**Table 2**

Demographic data and clinical features of patients in 2 groups (\( \bar{x} \pm s \)).

|                      | Control group (n = 50) | Treatment group (n = 53) |
|----------------------|------------------------|--------------------------|
| Age, yr              | 73.5 ± 3.8             | 72.5 ± 2.5               |
| MMSE                 | 15 ± 2.5               | 13 ± 4.2                 |
| WST                  | 4.2 ± 0.4              | 4.1 ± 0.8                |
| MNA                  | 8.9 ± 0.8              | 9.3 ± 1.1                |
| Hb (g/L)             | 102.3 ± 9.3            | 103 ± 6.2                |
| ALB (g/L)            | 36.4 ± 2.6             | 34.6 ± 1.7               |

ALB = albumin, Hb = hemoglobin, MMSE = mini-mental state scale score, MNA = Mini Nutritional Assessment, WST = water swallow test.

**Table 3**

The results of water swallow test in 2 groups.

| N0–N1   | 1 Excellent | =1 Effective | =0 Ineffective | <0 Deteriorated | Total |
|---------|-------------|--------------|----------------|----------------|-------|
| Control | 0           | 9            | 25             | 16             | 50    |
| Treatment | 0         | 33           | 15             | 5              | 53    |

N0 = pretreatment scores, N1 = posttreatment scores (12 weeks later).

**Table 4**

The results of different assessments in 2 groups during the treatment period (\( \bar{x} \pm s \)).

|                  | W4 Control group | Treatment groups | W8 Control group | Treatment groups | W12 Control group | Treatment groups |
|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Hb, g/L          | 105.8 ± 10.1     | 102.7 ± 7.7      | 102.6 ± 6.9      | 108.5 ± 10.2*   | 106.5 ± 4.1      | 107.3 ± 3.3      |
| ALB, g/L         | 32.7 ± 3.5       | 35.2 ± 5.9       | 32.5 ± 3.3       | 34.0 ± 4.3      | 32.2 ± 3.2       | 36.9 ± 3.8       |
| MNA              | 9.1 ± 1.9        | 10.4 ± 1.1       | 10.1 ± 1.0       | 11.0 ± 1.4      | 10.7 ± 1.1       | 13.2 ± 1.2       |
| MMSE             | 14.9 ± 2.9       | 15.3 ± 2.5       | 15.3 ± 2.7       | 15.6 ± 2.8      | 15.3 ± 2.4       | 16.3 ± 2.5       |
| WST              | 3.61 ± 0.57      | 3.78 ± 0.70      | 3.53 ± 0.54      | 3.49 ± 0.50     | 3.75 ± 0.70      | 3.26 ± 0.50*     |

ALB = albumin, Hb = hemoglobin, MMSE = mini-mental state examination, MNA = Mini Nutritional Assessment, WST = water swallow test.

*Control group versus treatment group, \( P < .05 \).
shown that swallowing function is closely related to the
insula,[24–29] which controls swallowing movements with the
synergistic action of precentral gyrus, postcentral gyrus, and
cingulate gyrus. AD mainly involves the forebrain, including
insula. AD patients in the medium and long term were
associated with different degrees of swallowing disorder,
usually complicated by aspiration pneumonia. It has a negative
impact on the patient’s recovery, extending the length of
hospital stay, increasing the economic burden on patients, even
the mortality.[30]

NMES stimulates muscle contraction mainly through low
frequency pulse current. Contraction and expansion of pharyn-
geal muscle can move the food into the esophagus, and thus help
to rebuild the control function of the brainstem reflex center over
swallowing reflex, improve blood circulation and the pharyngeal
muscle flexibility and coordination, and prevent pharyngeal
muscle atrophy. Meanwhile, the appropriate pharyngeal stimu-
lation help increase the pressure in the mouth, and improve
significantly or even restore the swallowing function. NMES
helps to strengthen the digestive function of oropharyngeal cavity
and esophagus and prevent food regurgitation and aspiration,
thereby reducing respiratory complications.[31]

EMG-biofeedback establishes a feedback path outside the
body and makes each of the correct processes learnt gradually
through repeatedly studying external signal conditioning,
improving the regulation of the swallowing function of the
cerebral cortex motor area and cortex edge. In addition to this,
low-frequency pulse current induces coordinated local muscle
contraction and expansion and increases the pressure within the
oral cavity and pharyngeal, moving the food into the esophagus.
By stimulating feedback loop, EMG-biofeedback treatment helps
restore normal reflex, promoting the central conduction pathway
formation.[32]

Related researches have proved that drug therapy can improve
dysphagia in AD patients with swallowing disorder,[33,34] but few
researches on rehabilitation treatment were reported. According
to the theory of neural plasticity and individual difference, the
rehabilitation training was treated with NMES and EMG-biofeedback
therapy. The purpose is to promote hemisphere function
remodeling and to establish the role of motor function in
feeding training. In the present study, we found that
swallowing function in patients was improved gradually with
the rehabilitation training. During rehabilitation training,
nutritional status was improved in both groups while the
rehabilitation group was improved more obviously. Since the
frequency and course of aspiration pneumonia were reduced,
the nutritional status was improved, which was indicated by the
results of MNA and the increased levels of the Hb in the 2 groups
after treatment. It is suggested that combination therapy with
NMES and EMG-biofeedback can reduce the frequency of
swallowing and shorten the course of the disease.

This study suggested that swallowing function of AD patients
can be improved through NMES and EMG-biofeedback. However, the present study mainly focused on the short-term
results, the long-term effect of NMES combined with EMG-
biofeedback remains to be confirmed by further researches.

5. Conclusion
In summary, NMES combined with EMG-biofeedback can
effectively improve the swallowing function of AD patients with
dysphagia and thus should be promoted in clinical practice.

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