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Chapter

# Neuromuscular Electrical Stimulation and Electromyographic Biofeedback as Adjunctive Modalities in the Treatment of Oropharyngeal Dysphagia in Stroke

*Cláudia Tiemi Mituuti, Marcela Maria Alves da Silva and Giédre Berretin-Felix*

## Abstract

Dysphagia is a symptom related to swallowing disorders that impede or hamper safe, efficient, and comfortable oral ingestion. In addition to compromising the swallowing process, dysphagia may impair overall health, the nutritional status, and lung conditions, impacting quality of life as well. Different proposals for the rehabilitation of oropharyngeal dysphagia have been researched over the years. As a therapeutic strategy aimed at the rehabilitation of oropharyngeal dysphagias, the electromyographic (EMG) biofeedback provides improved strength in swallowing and its coordination, understood as the best muscle recruitment during the function, associated with the attention and performance of cortical functions, simultaneously. Neuromuscular electrical stimulation (NMES) is another therapeutic approach used in the rehabilitation of oropharyngeal dysphagia (NMES). NMES has been recommended as an adjunctive modality to improve the results of exercises based on dysphagia therapy. In view of the possibility of using technological resources in the diagnosis and treatment of oropharyngeal dysphagia, this chapter presents the theoretical and procedural framework aimed at the application of EMG biofeedback and NMES as supporting methods in the treatment of oropharyngeal dysphagia, in cases affected by stroke.

**Keywords:** dysphagia, stroke, rehabilitation, electromyography, neuromuscular electrical stimulation

## 1. Introduction

Dysphagia is a symptom related to swallowing disorders that impede or hamper safe, efficient, and comfortable oral ingestion [1], characterized by the abnormality in the transference of bolus from the mouth to the stomach [2]. In addition to compromising the swallowing process, dysphagia may impair overall health, the nutritional status, and lung conditions, impacting quality of life as well [3, 4].

There are many neurological diseases that can affect the neural structures which control the complicated mechanisms of oropharyngeal swallowing. Most symptoms and complications from neurogenic dysphagia are due to sensory-motor change of the oral and pharyngeal phases of swallowing [5]. In adults and in the elderly population, dysphagia often derives from stroke [6].

Different proposals for the rehabilitation of oropharyngeal dysphagia have been researched over the years. Thus, literature review studies demonstrate the effectiveness of using protective and facilitating swallowing maneuvers, showing physiological changes in specific aspects of swallowing in normal subjects increasing or decreasing the pharyngeal contraction, the lingual pressure, the upper esophageal sphincter relaxation and contraction, according to the different techniques [7] and in the rehabilitation of oropharyngeal dysphagia reducing or eliminating aspiration and improving functional outcomes in specific populations [8, 9].

Orofacial myofunctional exercises are a therapeutic approach for the treatment of oropharyngeal dysphagia [10]. In poststroke individuals, tongue isometric exercises result in an increase in tongue force, with an associated improvement in swallowing pressure, airway protection, and tongue volume in acute or chronic phases [11].

In a late poststroke case, these tongue exercises were associated with improved bolus control and increased oral intake [12]. The use of surface electromyography (SEM) as a therapeutic biofeedback is a resource described in various areas of health, with studies showing clinical efficacy for a variety of neuromuscular disorders. The electromyographic biofeedback can be used to aid in muscle relaxation, coordination, and/or muscle response pattern training, as well as increased recruitment of motor units during muscular activity.

The McNeill Dysphagia Therapy Program (MDTP), which improves the timing of physiological events during swallowing, is another rehabilitation modality for patients presented with neurogenic dysphagia. Following MDTP, subjects presented with chronic dysphagia showed temporal coordination of swallowing components close to that of healthy individuals, thus suggesting a normalization of swallowing timing [13].

As a therapeutic strategy aimed at the rehabilitation of oropharyngeal dysphagias, the electromyographic biofeedback [14] provides improved strength in swallowing and its coordination, understood as the best muscle recruitment during the function, associated with the attention and performance of cortical functions, simultaneously [15, 16]. Its use has been described in cases of dysphagia due to stroke [17–20], as well as in cases of patients with sequelae from the treatment of head and neck cancer [19], with improvement in swallowing and consequent increase in the oral intake of patients treated with biofeedback associated with conventional therapy.

Neuromuscular electrical stimulation (NMES) is another therapeutic approach used in the rehabilitation of oropharyngeal dysphagia (NMES). NMES has been recommended as an adjunctive modality to improve the results of exercises based on dysphagia therapy. According to Wijting and Freed [21], NMES is the application of electrical current pulses to the skin to stimulate muscle contraction by peripheral motor nerves. The electric current causes a depolarization of the peripheral motor nerve, usually where the nerve enters the motor end plate, which, in turn, will elicit muscle contraction.

NMES has drawn the attention of speech therapists since the initial application for dysphagia by Freed et al. [22]. Some studies have shown improvement in swallowing physiology [22–24] and quality of life [25] after using NMES in individuals presenting with oropharyngeal dysphagia and also, specifically, in poststroke patients [26–28]. The increase in laryngeal excursion has been described as a

physiological change in swallowing following NMES, related to the lowering of the hyoid bone during rest, in patients with neurogenic dysphagia [29, 30], and to the increase in the elevation of the larynx during swallowing [31].

In studies reporting higher level of oral intake [31, 32], decreased severity of dysphagia in patients with moderate dysphagia [33], increased sensitivity in poststroke individuals [34], and decreased laryngotracheal aspiration [31] were found as well. On the other hand, some studies found no difference in the clinical outcomes of patients undergoing rehabilitation with NMES, as compared to conventional therapy [35, 36].

In view of the possibility of using technological resources in the diagnosis and treatment of oropharyngeal dysphagia, this chapter presents the theoretical and procedural frameworks aimed at the application of EMG biofeedback and NMES as supporting methods in the treatment of oropharyngeal dysphagia, in cases affected by stroke.

## 2. Neuromuscular electrostimulation

Regarding the effect of NMEE on swallowing, there is not a uniform stimulation protocol in terms of duration, number of sessions, and parameters of the electric current. Some studies show positive results of NMES in the treatment of dysphagia, but others suggest negative effects on hyolaryngeal elevation or do not find differences with respect to conventional therapy. It is known that NMEE can directly modulate swallowing and interfere with the mechanisms of central control and execution. In addition, the closure of the vocal folds during swallowing and speech is modified by NMES, owing to weakness and paresis [37].

Additionally, the physiological responses obtained by NMEE can also be influenced by age and level of stimulation. A study [38] found interactions between age and stimulation amplitude on lingual and pharyngeal functions during swallowing. The anterior tongue pressure was reduced by motor stimulation in both age groups; however, the posterior lingual-palatal pressures were selectively reduced in adults. The base of tongue (BOT) pressures were increased by sensory stimulation in the elderly but decreased in young adults. Hypopharyngeal pressures were increased in both groups by motor stimulation. Therefore, age and NMEE level should be taken into account when planning the rehabilitation of swallowing disorders.

Specifically on the effectiveness of the application of NMES in poststroke dysphagia patients, several methods are proposed for NMES application, including level of stimulation, electrode placement, tasks requested during NMES, and frequency and duration of sessions. Aiming at understanding how the research has been conducted, **Table 1** presents the information on the studies that included poststroke individuals, in their samples.

Studies with patients suffering from stroke who used the sensory level of stimulation showed improvement in swallowing function and that the increase in the sensorial input to the cortex can reduce swallowing problems. The thyrohyoid muscle stimulation was used in most studies, using motor stimulation to increase the elevation of the larynx.

Stimulation of the thyrohyoid muscle was used in most studies, using motor stimulation to increase the elevation of the larynx. Most studies show positive effects of NMES in the performance of swallowing in patients presented with poststroke dysphagia, especially when the stimulus is applied at the sensory level or when the level of motor stimulation is applied to the infrahyoid muscles, during swallowing [45].

| Research/authors | Beom et al. [39] | Kushner et al. [40] | Sun et al. [41] | Terré et al. [42] | Lee et al. [43] | Toyama et al. [44] |
|---|---|---|---|---|---|---|
| Stroke data | 2.4 ± 2.1 months after stroke<br>Cortex and subcortex | 15.7 days after stroke<br>Brain stem, brain hemisphere, and intracerebral hemorrhage | Brain stem and brain hemisphere | 5 and 7 months after stroke | 5.5 ± 2.1 day after stroke<br>Cortical and subcortical<br>Brain hemisphere | 25.2 ± 25.9 weeks after stroke<br>Hemorrhagic and ischemic |
| Age | 66.1 ± 19.5 years | 19–89 years | 70.1 ± 8.9 years | 32–71 years | 63.4 ± 11.4 years | 63.6 ± 21.4 years |
| Gender | 3 males and 4 females | 38 males and 27 females | 24 males and 5 females | 7 males and 2 females | 22 males and 9 females | 12 males |
| Stimulation level (device) | Tolerance (STIMPLUS DP200) | Tolerance (VitalStim) | Tolerance (VitalStim) | Tolerance (VitalStim) | 120% of the mean of 3 tolerance threshold measures (VitalStim) | Motor (HPC device) |
| Electrode placement | Near the motor point of the digastric anterior belly muscle | Different for each patient | A pair, horizontally, above the hyoid bone and another, on the thyroid cartilage | A pair, horizontally, on the mylohyoid muscle and another on the thyrohyoid one | Infrahyoid region | Region of geniohyoid, mylohyoid, and digastric anterior belly muscles and thyrohyoid musculature |
| Tasks required | None | Exercises to increase strength, resistance, and amplitude of movement and mobility of the orofacial, lingual, and laryngeal musculature | Repeated effort swallowing | None | Tactile-thermal stimulation, tongue and closing-elevation larynx exercises, effort swallowing, and Mendelsohn, Masako, and Shaker maneuvers | 3–10-minute NMES series, with 2-minute rest intervals, followed by conventional therapy with tongue exercises, tactile-thermal stimulation associated with dry effort swallowing, and Mendelsohn maneuver |
| Duration of sessions | 30 minutes | 60 minutes | 60 minutes | 45 minutes | 30 minutes with NMES associated with conventional therapy | 40 minutes |
| Number of sessions per week | 5 sessions | 5–6 sessions | 5 sessions | 5 sessions | 5 sessions | 5 sessions |
| Total of sessions | 20 sessions | 18 ± 3 sessions | 12 sessions | 20 sessions | 15 sessions | 40 sessions |

| Research/authors | Beom et al. [39] | Kushner et al. [40] | Sun et al. [41] | Terré et al. [42] | Lee et al. [43] | Toyama et al. [44] |
|---|---|---|---|---|---|---|
| Exams carried out | Assessment by ASHA NOMS protocol and videofluoroscopy | FOIS | Clinical assessment, FOIS, and perceptive evaluation of swallowing ability by the visual analog scale | FOIS, patient's satisfaction scale, and videofluoroscopy, after and 3 months following therapy | FOIS and videofluoroscopy | FOIS, videofluoroscopy, and assessment of the anterior and upper displacements of the hyoid bone and larynx |
| Results | Improvement in the dysphagia and ASHA NOMS scales and in the videofluoroscopy | Improvement in the FOIS scale and better FOIS score, as compared to controls | Improvement in the FOIS scale and maintenance from 6 months to 2 years<br>Improvement of the dysphagia degree and of the perceptive swallowing ability, following 6 months and stable after 2 years | Improvement in the FOIS and in the patient satisfaction scales<br>Decrease of aspiration and of the delay in the triggering of the swallowing reflex | Improvement in the FOIS and swallowing function, in all periods | Improvement in the FOIS and dysphagia scales<br>Greater anterior and upper displacement of the hyoid bone<br>Greater upper laryngeal displacement in the experimental group |

**Table 1.**
*Information on the studies that included poststroke individuals, in their samples.*

Thus, speech therapy sessions should be performed according to the selected therapy protocol, taking into account the characteristics of the patient's swallowing disorder and the goals to be achieved by the intervention.

Neuromuscular electrical stimulation is performed with a dual-channel electrotherapy system with an 80 Hz fixed current pulse and a 700 μs pulse duration (VitalStim, model 5900, Chattanooga Group), applied by a qualified professional.

Prior to placing the electrode in the skin, the anterior part of the neck should be cleaned with alcohol, so as to remove body oils that can interfere with the electrode contact. The placement of the electrodes used during therapy, for all participants, should meet their physiological needs of the patient. After placing the stimulation electrodes, the amplitude of the stimulation is increased by small increments.

The amplitude of the sensory and motor levels of NMES is determined based on the patient's description of the feeling, while the amplitude is increased from zero to the maximum tolerance. The minimum level of sensory stimulation is determined when the patient reports a tingling sensation, while the minimum motor level corresponds to sensation of tightness or pull [46].

The stimulation amplitude is set before therapeutic activities, individually determined at the motor or sensory levels, with functional tasks involving the swallowing of saliva or food of different volumes and consistencies, according to the possibility of safe feeding, identified by means of instrumental examination.

## 3. Surface electromyography and electromyographic biofeedback

Surface electromyography (SEMG) allows access to the physiological parameters of swallowing. Quantitative and qualitative analyses show that the normal swallowing in adults varies from individual to individual [47, 48] and is influenced by age. The pharyngeal phase is longer in children under 12 than in adults but with similar amplitude of muscle electrical signal [49], consistency, and bolus volume [50–52].

During electromyographic evaluation of swallowing, the activity of the suprahyoid muscles is 30–50% higher than that of the masseter muscles, and with advancing age, there is a decreased activity of the suprahyoid muscles and an increased masseter activity, with no statistically significant difference between men and women [47]. The literature has also shown a significant increase in the duration of muscle activity during swallowing, in patients over 70 years [53], and no difference between genders, both in the amplitude and duration of muscle activity, in the different age groups assessed [47, 53].

In addition to age, the use of dental prostheses influences the electromyographic activity. Authors [54] observed that, from the oral rehabilitation with implant-supported prostheses, the amplitude of the electromyographic signal for swallowing was the same found for dentate subjects, but the duration of muscle activity in this function is higher in users of prostheses. Authors [55] found a significant drop in activity for the masseter muscle following implant-supported oral rehabilitation in the elderly, resulting from the process of adaptation to the new conditions of stability generated by the fixation of total prostheses to the lower arch, in these subjects.

As an adjunctive method in the rehabilitation of oropharyngeal dysphagia, the electromyographic biofeedback can be used for the training of muscle relaxation, coordination, and/or muscle response patterns, as well as in the recruitment of a greater number of motor units during the activity of the stimulated muscle, in order to allow the patient to learn and monitor new muscle patterns using visual and/or auditory reinforcement [56, 57].

The application of electromyographic biofeedback in the treatment of dysphagia aims, primarily, at improving the swallowing strength and its coordination [16].

Studies show improvement in swallowing and, consequently, an increase in the oral intake of patients treated with biofeedback combined with conventional therapy [20, 24]. Research with this technique applied to swallowing disorders was initially carried out in a clinical case involving dysphagia of unknown etiology, which presented spasticity, rehabilitated with 20 sessions of EMG biofeedback and relaxation exercises to be done at home, with a significant improvement in the difficulty in swallowing, and maintenance of the results following 6 months of the end of the intervention [58].

The literature has shown improvement of swallowing in patients presented with poststroke neurogenic dysphagia, with an increased oral intake after the application of the biofeedback technique associated with conventional therapy, following seven training sessions [24] and after a 10-hour training carried out in a week [20], even in individuals previously rehabilitated with conventional exercises without success [20, 24]. A study [20] further reinforces that the functional improvement of swallowing was kept in six out of ten patients, up to 1 year after the intervention.

Another study examined the effectiveness of this technique in acute poststroke subjects using Mendelsohn's maneuver and EMG biofeedback for 2 weeks of rehabilitation and 2 weeks of non-rehabilitation, with groups which intercalated weeks of rehabilitation and non-rehabilitation and were assessed in each phase. In the rehabilitation week, the subjects were trained daily, twice a day, the first session being the learning of the maneuver and the remaining ones, training, during 30–40 swallowings. Significant changes were observed in hyolaryngeal duration and excursion (anterior and vertical), following the rehabilitation weeks [59].

Crary et al. [19] assessed the effectiveness of rehabilitation with EMG biofeedback in 25 patients presented with neurogenic dysphagia (poststroke) and in 20 subjects with mechanical dysphagia (posttreatment of head and neck cancer) in a 50-minute therapy, five times a week therapy, plus home training. All subjects improved their oral intake, with 92% improvement in neurogenic dysphagia and 80% in mechanics. Although the best result was seen in subjects presented with neurogenic dysphagia, they needed more sessions to complete the intervention, as compared to those with mechanical dysphagia.

Conventional therapy associated with electromyographic biofeedback should be performed during direct swallowing therapy, aiming at the learning of the new swallowing pattern. The strategies of the treatment with electromyographic biofeedback aim to achieve the neuromuscular adjustments required for the approximation of normal physiological patterns of the electromyographic recording, mainly of the suprahyoid muscles.

Additionally, the balance and coordination between different muscle groups, mainly those which elevate the jaw, orbicularis of the mouth, and suprahyoid muscles, can be approached, depending on the number of channels provided by the equipment. **Figure 1** illustrates the EMG biofeedback therapy.

The normal electromyographic pattern of swallowing and that performed by the patients should be presented to them, during the training, establishing a target track for functional training, in which the patients perform the enabling swallowing strategies, whose effectiveness must have been previously proven in the instrumental examination, aiming at approximating their neuromuscular recruitment to the normality physiological pattern, which involves, mainly, increasing the amplitude of the electromyographic signal of the suprahyoid muscles during function (greater muscle recruitment in the function). In addition, the functional training may aim at improving the coordination among other muscle groups involved in swallowing, increasing the recruitment of tongue muscle activity, in order to propel the bolus safely from the oral cavity through the pharynx, and increasing the amplitude of the muscle activity exerted during the effort of swallowing [16].



**Figure 1.**
*Patient and therapist during the direct training of swallowing, using the EMG biofeedback (4-channel neuroeducation equipment), monitoring the masseters, bilaterally, and suprahyoid muscles.*

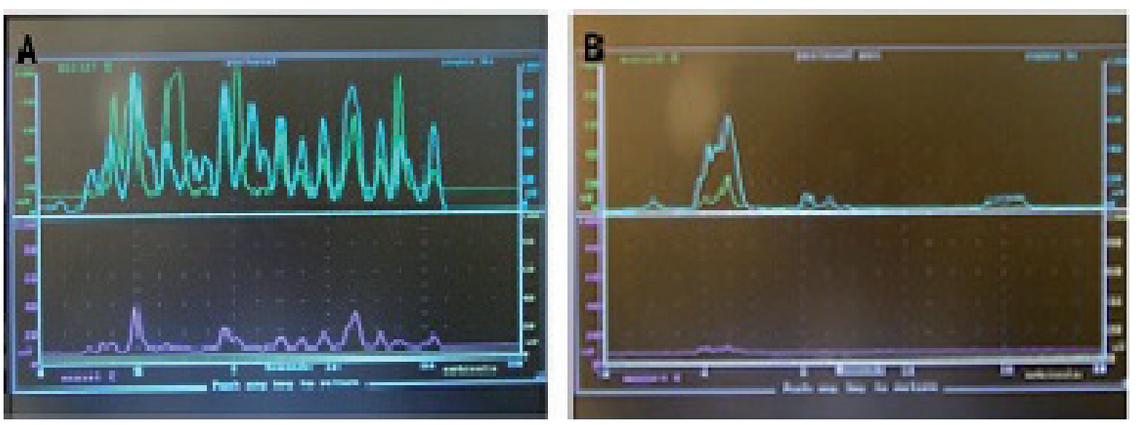



**Figure 2.**
*(A) EMG signal prior to therapy. (B) EMG signal after therapy.*

**Figure 2A** and **B** illustrate the neuromuscular behavior accomplished before and after a month of training, using biofeedback, whose sessions were held three times a week, in a patient presented with oropharyngeal neurogenic dysphagia with no success in the rehabilitation with conventional therapy.

The positive aspects of using the EMG biofeedback as an adjunctive method in cases of neurogenic dysphagia may pose this technique as a facilitator in terms of learning new neuromuscular patterns for swallowing, so as to provide the patient with a higher gain, as compared to the conventional therapy, as well as a probable longer effect of rehabilitation, since the EMG biofeedback involves the change of a previously learnt pattern, by means of the functional training therapy.

## 4. Conclusions

NMES has shown benefits in dysphagia therapy for individuals affected by stroke, mainly related to the classification of the degree of dysphagia and the level of oral intake. Some authors propose that the use of NMES associated with conventional therapy is more beneficial to the treatment of these individuals; however, there is a wide variety of electrode placement, level of the stimulus, and type and

location of the stroke; thus, further studies are necessary to prove the efficacy of this treatment modality.

On the other hand, swallowing training using EMG biofeedback can assist speech therapists in their clinical practice, enabling the patient to learn and monitor new muscle patterns, using visual and auditory reinforcement, and, from the learning and training of new neuromuscular recruitment, present a swallowing pattern as functional as possible, with a positive impact on quality of life.

However, further controlled and randomized clinical studies are necessary for a understanding on the contribution of the EMG technique, for there are still many doubts on the application method, the number of therapeutic sessions, and the characteristics of patients who can benefit from the training with EMG biofeedback.

## Conflict of interest

The authors declare no conflict of interest.

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