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ORIGINAL STUDY

Preliminary outcomes in transcutaneous neuromuscular electrical stimulation use in patients with dysphagia

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ABSTRACT

Dysphagia is a common disorder associated with a large number of etiologies like aging, stroke, traumatic brain injury, head and neck cancer, neurodegenerative disorders, structural changes or congenital abnormalities. The type of the treatment and its results depend on the type, severity and the cause of dysphagia. The primary goal of dysphagia treatment is to improve the swallowing process and decrease the risk of aspiration.

Along with the existing rehabilitation swallowing treatments, new adjunctive therapy options developed, one of them being the neuromuscular electrical stimulation (NMES).

The authors present the principles of NMES, a small literature review about the results of this therapy and their experience in using transcutaneous NMES in dysphagia patients.

KEYWORDS: neuromuscular electrical stimulation, dysphagia, electromyography, transcutaneous.

INTRODUCTION

Dysphagia is a common disorder associated with a large number of etiologies like aging, stroke, traumatic brain injury, head and neck cancer, neurodegenerative disorders, structural changes or congenital abnormalities[1-5]. The reported incidence of swallowing disorders is up to 70% in patients post-stroke[6,7], 65% in patients with traumatic brain injury[8] and of almost 22% in adults over 50 years old[9].

The swallowing process can be divided into three phases: oral, pharyngeal and esophageal. Either of them can be affected and responsible for the installation of dysphagia. During swallowing, the larynx elevates and protects the upper airways, while the upper esophageal sphincter relaxes and opens. It is considered that the most severe dysphagia appears the moment laryngeal elevation is reduced or delayed, due to the high risk of aspiration[10,11].

Taking into consideration that dysphagia is associated with a high mortality, an increased morbidity (malnutrition, dehydration, aspiration), and dependence on feeding tubes, an efficient treatment is necessary. In the literature, a high variety of treatment modalities for dysphagia are presented[1,10,12]. The type of the treatment and its results depend on the type, severity and the cause of dysphagia.

The primary goal of dysphagia treatment is to improve the swallowing process and decrease the risk of aspiration. Each treatment protocol for swallowing disorders has three important components: restitution, compensation, adaptation[13]. Restitution implies the total or partial recovery of swallowing and it consists in thermal and/or tactile stimulation, mobilization and movement exercises (for the lips, the tongue and the larynx). Different swallowing manoeuvres, like normal or effortful swallowing, Mendelsohn manoeuvre, Masako manoeuvre, supraglottic swallowing, or posture changes (head flexion or rotation, chin-tuck) are compensatory strategies which can improve the existing swallowing functions. An important part of the dysphagia treatment is the adaptation of food consistency, chewing time to the existing disabilities.

Along with the existing rehabilitation swallowing treatments, new adjunctive therapy options developed, one of them being the neuromuscular electrical stimulation.

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THE PRINCIPLES OF NEUROMUSCULAR ELECTRICAL STIMULATION

Neuromuscular electrical stimulation (NMES) therapy represents the application of an electrical current to the periphery of a certain target[5]. The first studies date from the '90s. In 1996, Freed introduced the transcutaneous NMES of the neck in dysphagia patients[14]. One year later, Park et al.[15] used a palatal prosthesis to deliver an electrical impulse while swallowing. The second study results showed an increase in post-stroke swallowing function in almost 50% of the studied patients.

From the physiologic point of view, swallowing is a complex process that involves the activity and coordination of no more than 26 muscles and 5 cranial nerves. All these anatomical structures are involved in at least one of the three phases of swallowing. In this context, NMES aims to strengthen the swallowing musculature and avoid muscle atrophy by causing contraction, and to stimulate the sensory pathways involved in the swallowing process[1,5].

The sensorial threshold is identified at the lowest electrical current intensity at which the patient feels a tingling sensation on the skin. It was demonstrated that this therapeutic stimulation is useful in the long-term reorganization of the cortex, this process being a key in the rehabilitation of the swallowing action[16-18].

The motor threshold is the second step one should take when using NMES. The contraction of the muscle is used for strengthening the muscles and protecting them from fibrosis or atrophy. It is well known that the neuromuscular electrical stimulation influences the contractions of the type II muscle fibres, which are involved in forceful and high-speed contractions[10,16,19]. On the other hand, the type I muscle fibres are activated by the traditional rehabilitation swallowing therapy. So, one can say that the combination of the two treatment methods implies the activation of both muscle fibres types and in this way it may increase the positive results of the rehabilitation process[10,16]. From our experience, using both NMES and classical exercises (head rotation and flexion, chin-tuck, supraglottic swallowing, Mendelsohn manoeuvre , Masako manoeuver) gives better results in what the dysphagia patients' recovery is concerned than NMES alone. The voluntary muscle contraction associated with the electrical stimulation seems to produce a higher activation of the central nervous system than the electrical stimulation alone[20]. By using corticobulbar motor evoked potentials, Doeltgen[21] presented better results in those patients in whom NMES was associated with voluntary muscle contraction, with a persistence of high potentials even one hour after the treatment.

While performing the combined therapy (NMES and voluntary contractions), the so-called motor adaptation/recalibration appears and it can last a long time after the cessation of the treatment. When a deficit in the hyolaryngeal excursion and/or the larynx closure is present, the electrical stimulation of the muscles responsible for the larynx elevation or the closure of the laryngeal vestibule determines a motor recalibration, which improves the larynx movement during the pharyngeal phase of swallowing[22]. These phenomena are influenced by the electrodes and their placement.

The electrode placement is very important in transcutaneous neuromuscular electrical stimulation. The most important stimulated area is the anterior neck region – the upper submental region and the inferior throat region located under the hyoid bone. The submental region is the area which lies between the mandible and the hyoid bone. When applying the electrical stimulation, the superficial muscles are first stimulated. As the intensity of the stimulus rises, the profound muscular layers will be reached. Depending on the region the electrodes are placed, different muscle groups are stimulated and different swallowing mechanisms are influenced.

The stimulation of the submental region supports the laryngeal elevation during swallowing. The targeted group muscles in this region are: the anterior belly of the digastric muscle, which elevates the hyoid bone when the teeth are closed, the mylohyoid muscle involved in the raise of the hyoid bone toward the mandible, the geniohyoid muscle that is responsible for the hyoid anterior and upward movement[23].

In case of infrahyoid muscles electrical stimulation, we refer to the sternohyoid muscle which pulls the hyoid bone towards the sternum, the omohyoid muscle that is responsible for moving the hyoid laterally and downwards, the thyrohyoid muscle involved in the larynx elevation[23]. All these muscles are responsible for the closure of the vocal folds and for lowering the larynx.

The neuromuscular electrical stimulation can be also used on facial muscles which are involved in the oral phase of the swallowing process[24,25]. The facial muscles (buccinator, orbicularis oris, risorius) contribute to mastication, bolus manipulation and formation of the intraoral pressure during the oral phase.

In the literature, many benefits of neuromuscular electrical stimulation therapy are described. It was shown that NMES can improve swallowing, both sensorial and motor functions, and it can help the patient gain a better coordination during the swallowing process[1,26,27]. But there are also authors who do not present conclusive results in what this therapy is concerned. The main perceived disadvantage of NMES is the high cost related to the device and the consumables, followed by the electrode placement and time-consuming nature of the rehabilitation programme[1].

PRO AND CONS OF NMES

In the literature, there are several studies analysing the effect of neuromuscular electrical stimulation in treating dysphagia patients.

Some studies sustain the positive effect of the swallowing rehabilitation by using NMES[10,13,20,28-32]. Ludlow et al.[28], in a study conducted in 2007 on 11 patients with pharyngeal dysphagia of different etiologies, reported a decrease in aspiration phenomena and penetration after electrical stimulation, by measuring with videofluoroscopy the hyoid movement and the subglottic air column position. They used for the stimulation the VitalStim® device, on both maximum tolerated intensity level and lowest sensory level. Also by using VitalStim® therapy on patients with chronic dysphagia of different etiologies, Carnaby-Man and Crary showed an improvement in the swallowing ability and the functional oral intake[29]. The first two studies had no control group included. If we take into consideration this aspect, in 2009, Lim et al.[30] evaluated the effect of neuromuscular electrical stimulation on patients with dysphagia post-stroke. They compared the effect of electrical stimulation with VitalStim® (using the sensory threshold) combined with thermal-tactile stimulation, with the effect of thermal-tactile stimulation only. The results suggested that the combined therapy presents better results than thermal-tactile stimulation alone.

In a study performed in 2011, Verin et al.[31] evaluated the achievement of submental sensitive transcutaneous electrical stimulation applied during swallowing in patients with chronic neurologic disorders. After a six-week treatment, the swallowing coordination improved and the aspiration decreased.

Evaluating the effect of motor electrical stimulation versus sensory electrical stimulation, Park et al.[32] combined each stimulation type with effortful swallowing in a randomized controlled study in patients with post-stroke dysphagia. The results showed a significant increase in the displacement of the larynx ($p<0.05$), in the vertical displacement of the hyoid bone and the width of the upper esophageal sphincter ($p=0.066$) in the experimental group (effortful swallow combined with motor electrical stimulation) and no increase in the control group (effortful swallow and sensory electrical stimulation).

In a study performed on healthy subjects, Watts et al.[20] present the effect of NMES on the laryngeal vestibule closure. Associating dry swallows with submandibular muscle electrical stimulation, the authors indicate a significant effect of stimulation on the laryngeal vestibule closure reaction time and duration after the stimulation compared with pre-stimulation measurements.

There are also many studies presenting a negative effect of neuromuscular electrical stimulation or no significant difference between electrical stimulation therapy and traditional dysphagia treatment[13,33-37]. Studying the effect of surface electrical stimulation in normal volunteers, with the placement of different electrodes, Humbert et al.[33] concluded that surface stimulation "would not be an acceptable alternative to the more invasive intramuscular stimulation for enhancing the hyolaryngeal elevation in dysphagia". Evaluating the effect of NMES on the submental muscle activity in patients with pharyngeal dysphagia, Suiter et al.[34] stated that the benefit of this therapy is not supported.

Comparing the therapeutic effects of electrical stimulation with those of conventional dysphagia management, Boem et al.[35] demonstrated no significant difference between the two patient groups in what the videofluoroscopic dysphagia scores and the ASHA level are concerned. In 2012, Heijnen et al.[36] evaluated the quality of life in patients with Parkinson's disease after neuromuscular electrical stimulation versus traditional therapy. They randomly formed three patient groups: one group received traditional logopedic dysphagia treatment, the second and the third group received traditional therapy combined with sensor, respectively motor electrical stimulation. At the end of the treatment, a significant improvement in Dysphagia Severity Scale scores was seen in all groups and restricted improvements in patients' quality of life. But, there was no significant difference between the three groups.

Following the same idea, Kiger et al.[37] compared the outcomes using VitalStim® therapy versus traditional swallowing therapy. They used two groups – the experimental group that received VitalStim® therapy and the control group that received traditional therapy. The analysed parameters were represented by changes in the oral and pharyngeal phase, dysphagia severity, dietary restrictions, progression from non-oral to oral intake. The results showed no statistically differences between the two therapies outcomes.

OUR EXPERIENCE

Starting from October 2017, we have been using in our clinic the transcutaneous neuromuscular electrical stimulation for the rehabilitation of dysphagia patients and facial nerve palsy. In Romania, the ENT Sarafoleanu Medical Clinic from Bucharest has the first otorhinolaryngological medical team who performs NMES in patients with different grades and causes of dysphagia.

The rehabilitation therapy is performed by using

Figure 1 VitalStim® Plus Electrotherapy System (Chattanooga Group, Chattanooga, TN, USA), a 2-channel surface electromyography (sEMG) and 4-channel electrotherapy.

the VitalStim® Plus Electrotherapy System (Chattanooga Group, Chattanooga, TN, USA), a 2-channel surface electromyography (sEMG) and 4-channel electrotherapy (Figure 1).

The therapy protocol is in accordance with the indications offered by the developers of the technique[10,38]. The electrode placement depends on the swallowing deficits of each patient and can involve only 2 channels of all 4. According to the certification course and training manual, the number of sessions after which patients can see good results of the therapy stands between 5 and 12, 1 hour/session/day, 5 days/week[10,38]. In Romania, the costs of this kind of therapy are not supported by the health insurance, the consequence being a high cost of the treatment. For these economical reasons, till now we performed for each patient 4 therapy sessions, 1 hour/day, 4 consecutive weeks, with good results. The protocol consists in VitalStim® therapy, manual control mode, phase duration 300µs, frequency 80pps, ramp time 0.5 seconds, the stimulation being at the motor thresholds. We can also use sEMG work / rest assessment for evaluating the patient progress.

Each patient with swallowing disorders is evaluated by performing a flexible laryngeal endoscopy to evaluate the local status, the existence of associated pathology like vocal fold paresis or hypotonic pharyngeal wall, the presence of endolaryngeal penetration and aspiration, salivary stasis.

The pretreatment evaluation consists also in the evaluation of patients' dietary status, aspiration presence, swallowing delay, laryngeal elevation, and subjectively by using the Functional Oral Intake Scale (FOIS) for the diet, the Eating Assessment Tool (EAT-10) to assess the swallowing difficulties.

In all patients we use combined therapy – neuromuscular electrical stimulation and voluntary contractions during the session (water and food ingestion, Masako manoeuvre, supraglottic swallowing), home exercises.

We present the preliminary outcomes of NMES therapy in patients with pharyngeal dysphagia of different etiologies and severity grades. For this, the patients were included in distinctive categories: dysphagia secondary to neurosurgical interventions (e.g. vagus nerve schwannoma surgery, glomus jugulare tumor surgery), dysphagia secondary to neurologic disorders (Parkinson's disease, amyotrophic lateral sclerosis, post stroke), dysphagia secondary to autoimmune diseases (like Sjogren's syndrome, polyneuropathy), dysphagia secondary to ENT surgery, dysphagia secondary to radiotherapy.

Before the treatment, dysphagia was associated with the sensation of food sticking in the throat, post-ingestion cough, aspiration and penetration phenomena. There were cases in which dysphonia was present, due to a vocal fold paralysis, or facial nerve palsy.

The flexible laryngeal endoscopy revealed salivary stasis at the level of the pyriform sinuses and/or vallecula, endolaryngeal penetration and aspiration and, in postradiotherapy cases, edema of the arytenoids and interarytenoid mucosa.

The initial FOIS scores varied between 4 (total oral

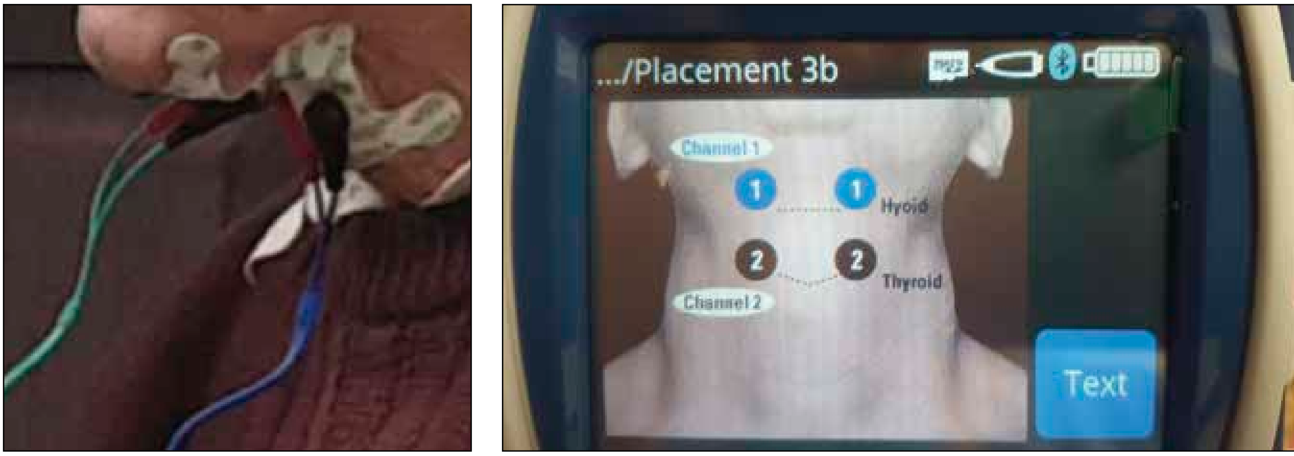

Figure 2 The 3b electrode placement (a. on a patient; b. electrode placement graph according to the device software[38].

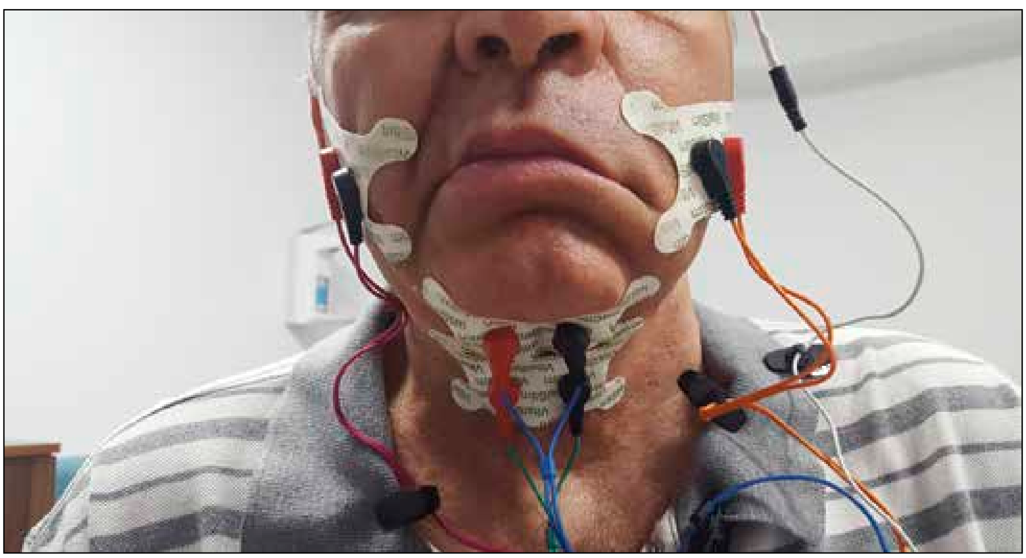

Figure 3 4a and 3 b electrode placement in a patient with dysphagia and left facial nerve paresis.

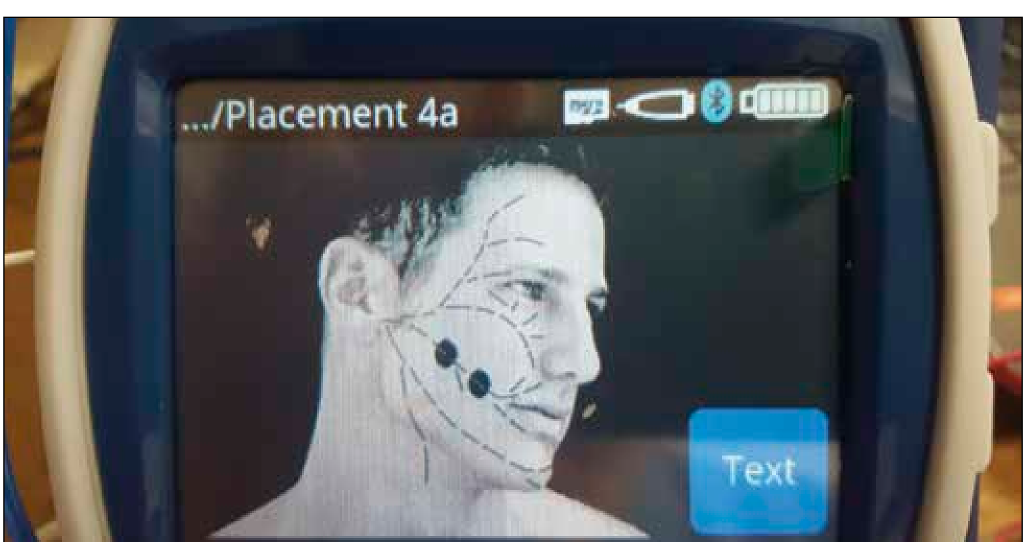

Figure 4 The 4a electrode placement graph according to the device software[38].

intake of a single consistency) and 6 (total oral intake with no special preparation but must avoid specific foods or liquid items), and the EAT-10 scores between 8 and 34.

The swallowing rehabilitation therapy consisted in 4 sessions, 60 minutes/session, one session per week, of VitalStim® stimulation. We used two or four stimulation channels. The electrodes were placed in accordance with the 3b placement (Figure 2) or a combination of 3b and 4a (Figure 3). For the 3b placement, the first electrode pair was placed in the submental region stimulating the anterior belly of the digastric muscle, the geniohyoid and the mylohyoid muscles. The submental electrode can be used for sEMG. The second electrode pair was placed over the thyroid to stimulate the infrahyoid muscles.

The 4a position implies two electrodes on each buccal branch of the facial nerve (right, respectively the left one), for the stimulation of the orbicular oris, buccinator muscles (Figure 4).

The stimulation threshold intensity varied between 4mA and 11mA.

After 4 sessions of NMES swallowing rehabilitation and home exercises, the patients related an improvement in the swallowing process and coordination, less or no coughing episodes after food ingestion, a decrease in the sensation of food stuck in the throat. A change in dietary consistency and variability was also present – the Functional Oral Intake Scale scores varied between 5 (total oral intake of multiple consistencies requiring special preparation) and 7 (total oral intake with no restriction).

The fiberoptic laryngeal examination revealed a significant reduction or absence of the salivary stasis and the endolaryngeal penetration and aspiration. There was no change in the vocal fold paresis, but with a good compensation by the normal movement of the contralateral vocal fold.

The EAT-10 presented an important decrease, the score variyng between 4 and 20.

The therapy progression was also demonstrated by the sEMG rest/work assessment (Figure 5). In those cases with dysphagia secondary to neurologic pathology, like amyotrophic lateral sclerosis and Parkinson's disease, the assessment showed an increase in work – swallowing efficiency and coordination, and an increase in the delay onset of swallowing, which can be attributed to the natural evolution of the neurologic disorder (Figure 6, Figure 7).

CONCLUSIONS

Even if our experience in using transcutaneous neuromuscular electrical stimulation in the swallowing rehabilitation is limited till now, we can state that this new therapy in an important and efficient tool in helping dysphagia patients.

The positive results depend on the severity and the causes of dysphagia. We sustain the idea that more than four therapy sessions are needed in moderate and severe cases.

As described in the literature, we also confirm that the combined therapy – NMES and voluntary contractions – brings the best results in treating dysphagia patients. The association of home exercises can be the key for the positive results in the swallowing rehabilitation process.

Conflict of interest: The authors have no conflict of interest.

Contribution of authors: All authors have equally contributed to this work.

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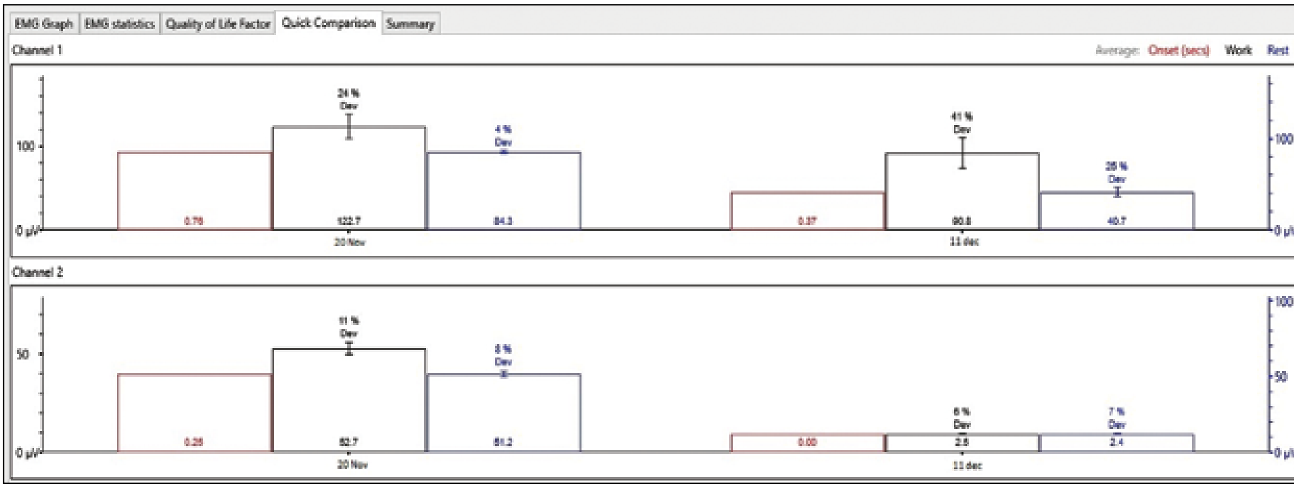

Figure 5 sEMG rest/work assessment – improvement in swallowing timing and coordination.

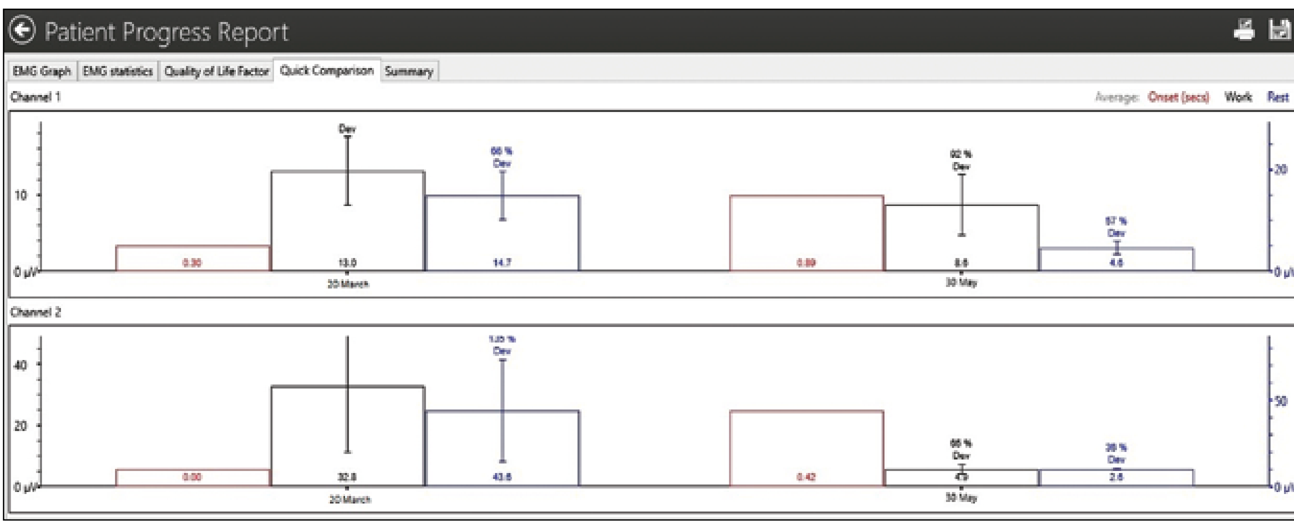

Figure 6 sEMG work/rest assessment results in dysphagia associated with amyotrophic lateral sclerosis – delay in deglutition onset, an improvement in the swallowing duration.

Figure 7 sEMG work/rest assessment in dysphagia associated with Parkinson's disease – delay in deglutition onset, improvement in swallowing timing.

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