The use of EMG biofeedback and electrostimulation in the treatment of dysphagia

ENRAF NONIUS

Partner for Life

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1. Introduction

Swallowing would appear to be the most normal thing in the world. A healthy adult swallows between 800 and 2400 times a day, largely depending on the amount of food and liquids taken.

A healthy person swallows without thinking about it, it happens almost automatically. However, the normal swallowing reflex is an extremely complicated interplay between various muscles, with timing, coordination, feeling and muscular strength all playing a significant role. When this process is disturbed, it can result in swallowing problems.

Dysphagia can be caused by different pathologies, such as Stroke and neurogenic disorders, but also by the natural ageing process. These disorders are particularly disabling and form a significant problem in the patient's daily life.

With the aid of EMG biofeedback, many of these patients can receive considerable benefits. The treatments are not invasive and have a very long-lasting effect.

As well as practice therapy with EMG biofeedback, a very good result can also be achieved with electrostimulation.

This paper explains the aetiology of dysphagia and describes the different types of treatment using EMG biofeedback and electrotherapy. Apart from theoretical considerations, valuable practical tips and proposals for treatment are given for treating dysphagia.

The findings in this paper are based on empirical research at the Academisch Medisch Centrum in Amsterdam and on data from the literature. A number of abstracts are included.

This paper is intended for professional practitioners in the health care services. Before using the therapeutic recommendations and applications, it is essential that the practitioner is aware of the risks associated with the various applications. The instructions in the user manual of the relevant machine must be strictly followed at all times.

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2. Normal deglutition and swallowing problems

2.1. Normal deglutition

A healthy adult swallows between 800 and 2400 times a day, largely depending on the amount of food and liquids taken. A healthy person swallows without thinking about it, it happens almost automatically. The normal swallowing reflex is an extremely complicated interplay between various muscles, with timing, coordination, feeling and muscular strength all play a significant role. When this process is disturbed, it can result in swallowing problems.

Swallowing is subdivided into four phases (Logemann, 1999)

- oral phase
- transport phase
- pharyngeal phase
- oesophageal phase

2.1.1. Oral phase

In this first phase, someone takes a bite or a sip. The mouth is opened, a bite/sip is taken and the mouth is closed. In the case of hard consistencies, chewing follows: a grinding movement with the jaws. The cheek muscles are tightened to prevent remnants of food remaining in the cheek pouches. Chewing mixes the food with saliva and prepares it for swallowing. When the chewing process is completed, the food bolus is collected in the centre of the tongue and the person is ready to swallow. It is important to realise that in this phase, swallowing is entirely voluntary.

2.1.2. Transport phase

When the food bolus has been collected in the centre of the tongue, we place the tip of our tongue behind our front teeth to create a groove in our tongue, which allows the food bolus to slide to the pharynx (the throat). If we initiate the swallow, the bolus does not slide only by itself; the tongue makes an undulating movement so that the food bolus is transported to the back of the mouth. At the end of this phase, the swallowing reflex is stimulated; from now on swallowing is wholly a reflex action.

2.1.3. Pharyngeal phase

The stimulation of the swallowing reflex starts the pharyngeal phase; this is the most complex phase of swallowing. The soft palate is pulled up to ensure that the food does not return through the nose. The vocal cords are closed and the larynx moves upwards, so that the epiglottis closes the trachea, ensuring that the food cannot reach the trachea during swallowing (choking). The muscles in the throat wall transport the food bolus to the oesophagus.

2.1.4. Oesophageal phase

In this phase the food bolus is in the oesophagus and is transported to the stomach by peristaltic contractions. With the mouth and throat empty, the tongue and muscles in the neck relax; as a result, the larynx descends and the vocal cords open.

2.2. Swallowing problems

If something goes wrong in the interplay between the various muscles involved in swallowing, a person can choke. Choking and the accompanying coughing is the most common form of dysphagia. Dysphagia can also lie in the oral phase of the transport phase; patients who can no longer chew or who have problems transporting the food from the mouth to the throat.

2.3. Consequences of swallowing problems

Everyone chokes sometimes, but this seldom causes problems in a healthy person. When there are chronic swallowing problems, however, it can cause a life-threatening situation.

2.3.1. Aspiration (pneumonia)

Food in the lungs is called “aspiration”. Aspiration can lead to (fatal) pneumonia, also called aspiration pneumonia (Langmore, 1998). One problem is that in some cases patients choke (and therefore get food in the lungs) without coughing; due to a disorder, the coughing reflex is no longer active and these people aspirate without being aware of it. This can result in an extremely serious situation.

2.3.2. Feeding problems

When swallowing problems prevent patients from eating certain consistencies properly, they will try to avoid these in their daily diet. This can result in situations in which the patient is eating a limited diet or not getting sufficient nourishment. For this reason, if a patient has swallowing problems it is important that not only the speech therapist is involved in determining the nature of the problem, but also that the dietician is consulted to establish a good diet (Bogaardt, 2001).

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2.3.3. Costs of swallowing problems and tube feeding

An estimate of costs shows that one day's enteral feed (tube feed) costs about €14.50 in food and €7.00 in material costs, such as feed pumps and maintenance. Furthermore, a PEG tube needs to be changed with some regularity. When all the costs are added together, one year's complete tube feeding costs the health care insurer about €10,000 per PEG tube (Bogaardt, 2005).

2.4. Literature

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3. Swallowing problems in different patient groups

3.1. Neurologenic dysphagia

Patients who have had a stroke generally have a lot of problems with thin liquids. Due to the loss of feeling at the back of the throat and possibly due to paralysis, the coordination between swallowing and closing the trachea is disrupted. As a result, these patients choke. Another problem is that the lips cannot close properly due to facial paralysis, or the piece of food cannot be collected in the centre of the tongue due to paralysis of the tongue muscle, so that food remnants remain in the mouth. Other neurological causes of swallowing problems are muscle disorders; due to general muscle weakness, chewing is difficult and the muscles at the back of the throat can no longer transport the food properly towards the oesophagus. These patients often have problems with hard consistencies rather than with thin liquids.

3.1.1. Swallowing problems after cerebrovascular accident (Stroke)

In 2002 the World Health Organisation calculated that about 15 million people worldwide suffer a Stroke every year; one in 450 people have a stroke every year.
Swallowing problems occur in about half of these patients (Doggett, 2001). In many patients, the swallowing function recovers well in a short space of time (two months), but in a small group recovery can take many months to several years (Aydogdu, 2001). A prospective study into recovery from swallowing problems in neurological patients shows that the average duration of logopaedic treatment for these patients is two months for patients who are wholly or partially dependent on tube feeding. Of this patient group, only 55% recovers to the extent that tube feeding is no longer necessary (Prosiegel, 2002). In a large group of patients this recovery does not occur.

It is not known exactly how many patients receive long term tube feeding after a Stroke. Elia (2001) states that in England this is the case in 1.7% of Stroke patients. Figures from a Canadian study (Teasell, 2001) suggest that 1.25% of all Stroke patients still relies wholly or partially on tube feeding after one year.

Generally it can be stated that Stroke patients are probably discharged from logopaedic treatment six to twelve months after a Stroke, because no further recovery is expected. When there are still swallowing problems at the end of the treatment period, the patient often requires (partial) tube feeding for an extended period of time.

3.1.2. Swallowing problems in degenerative neurogenic disorders

In many degenerative disorders, swallowing problems occur in different degrees of severity. It is difficult to say, however, which problems occur specifically with these conditions. There appears to be a large variability in the time between diagnosis and the occurrence of swallowing problems. Certain degenerative conditions can first become manifest with a swallowing problem (e.g. bulbar forms of amyotrophic lateral sclerosis (ALS) and Inclusion Body Myositis (IBM), while in other disorders, the swallowing problem only starts to play a significant role when the disorder is at an advanced stage.
The treatment of swallowing problems in degenerative conditions consists predominantly of advice on posture while eating and drinking and learning compensation techniques. Exercises to strengthen particular muscles or muscle groups is usually contraindicated for these patient groups.

3.2. Dysphagia in Head-and-Neck-cancer

Problems can also occur after operations in the head-neck area, for example because muscles have been partially or completely removed. The severity of the swallowing problem will in many cases depend on the location of the tumour and the nature of the operation. Apart from a major operation, patients will in most cases also receive radiotherapy, which can result in dysphagia, or worsen existing swallowing problems.
As a result of the radiotherapy, the muscles become stiff, so that the larynx has difficulty moving. Apart from this, insensibility can occur in the throat, so that patients choke more easily.
The therapy for these patient groups is geared mainly to learning compensation techniques, as in many cases the muscles required for safe swallowing have been removed or otherwise affected.

3.3. Presbyphagia

An important form of swallowing problems is ‘presbyphagia’, dysphagia connected with ageing. Old age is accompanied by weaknesses, which in the case of swallowing may mean the muscles working less forcefully and the whole swallowing process becoming slower. Older people often have more problems with thin drinks (due to the slowing down of the swallowing process) and hard consistencies (less strength for chewing).

Ekberg (2002) states that one in three older people in European nursing homes has problems swallowing. In 70% of these cases there is no professional treatment for these symptoms. Half of these patients say they eat less and 44% say they have involuntarily lost weight over the previous twelve months. This study also looks at the psychosocial aspects of dysphagia; 41% of patients is afraid of choking at meal-

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times, and a large group of patients (36%) avoids eating in a group due to embarrassment.
In 1997, Steele found that a large group of nursing home residents had swallowing problems. In her study, however, she also pointed out that these problems do not occur in isolation. Apart from swallowing problems, problems with correct posture and behavioural problems also appear to play a role in dysphagia (Steele, 1997).

One possible cause of this is staff shortages, as a result of which patient care comes under pressure. In many cases an overly cautious approach is taken with regard to swallowing problems, possibly due to pressure of time, and in many cases due to poor diagnosis. Groher (1995) states that 91% of nursing home residents has a diet that is too restrictive, which must have a significant effect on the quality of life of these patients (Gustafsson, 1991).

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4. Speech therapy for swallowing problems

The functional speech therapy (dysphagia therapy) for swallowing consists of three different approaches (Logemann, 1999):

- swallowing rehabilitation
- compensation strategies
- dietary adjustments

4.1. Swallowing rehabilitation

Swallowing rehabilitation consists of exercises that train particular muscles or muscle groups. This may, for example, be exercises that improve the function of the tongue muscles, so that the patient is able to make a better, more homogeneous bolus in the mouth prior to swallowing.
There are also exercises to improve larynx elevation and pharynx contraction. When one looks at the physiology of the normal swallowing movement, one finds that for every abnormality in this movement there are specific exercises. Swallowing rehabilitation is aimed at restoring the function of specific muscles; during the exercises it is only these muscles that are exercised. Swallowing rehabilitation is therefore often a question of 'dry' exercises; there is no oral intake.

4.2. Compensation strategies

Compensation strategies give the patient the opportunity to overcome the swallowing problems, without the underlying cause being removed. The patient learns how he can avoid problems during eating and drinking (such as choking, coughing).
Compensation strategies are mainly aimed at changing the position of the head and at certain ways of swallowing. An example of a compensatory strategy is swallowing with so-called subglottal pressure build-up. The patient learns to block his breathing before swallowing. If the patient pushes forcefully, both the true and false vocal cords close; aspiration of food cannot occur as easily with a reduced larynx sphincter function. As with swallowing rehabilitation, there is a compensation strategy for nearly every type of swallowing movement disorder.

4.3. Dietary adjustments

A third therapy option is to change the patient's diet. A swallowing video and other aids are used to determine which consistencies the patient can swallow without problems, and in what quantities. With neurological patients there is a significant chance that aspiration will occur with thin liquid consistencies. When a swallowing video shows that thick liquid consistencies are not aspirated, the thin liquids in the patient's diet can be thickened with specially developed thickening agents. There are also ready-made 'thickened' drinks on the market. Thickening drinks can allow a patient to receive his daily fluid intake, so that a tube will not be necessary.

Apart from changing the consistency of the food, the temperature can also be adjusted. It is well-known that the swallowing reflex is more sensitive to cold stimuli than to hot ones. With patients with neurogenic dysphagia, it is therefore advisable to practice in particular with cold food, such as ice water, cold custard, etc.

4.4. Literature

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5. The use of EMG biofeedback in the treatment of dysphagia

5.1. EMG biofeedback

Biofeedback is defined as “the use of technical devices to explain the internal physiological processes to the patient by means of visual or auditory signals, so that the patient can consciously learn to influence these processes by manipulating the signals” (Huckabee, 1999). Surface electromyography (EMG) as biofeedback gives the patient the opportunity to develop a greater awareness of muscle activity during swallowing, through continuous visualisation of the electrical activity in the muscles on a screen. The visual feedback allows the patient to see the smallest change in the tightening of a muscle, so that he can develop greater control over these muscles.
The use of surface EMG as biofeedback is relatively new in dysphagia therapy; this treatment method has been used sporadically since 1990. Research into the possible effects of using surface EMG in the treatment of swallowing problems was not carried out until 1995 (Crary, 1995). This chapter discusses this treatment and presents a patient series.

5.2. Treatment and effectiveness

The effectiveness of EMG biofeedback has already been proven in the past few decades in different treatments and in different patient groups. A number of meta-analyses and reviews on treatments in which EMG biofeedback is used have been published. In these publications a positive effect comes to the fore. Schleenbaker et al (1993) find, for example, that EMG biofeedback is an effective instrument for neuromuscular rehabilitation following a stroke. More recently, Moreland et al (1998) published a meta-analysis in which it was argued that therapy with EMG biofeedback is superior to conventional therapy where improvement of muscle strength with dorsiflexion of the ankles is involved.

5.3. EMG biofeedback: treatment of swallowing problems

The electrodes of the EMG machine are positioned under the chin, on the mouth floor (Figure 5.1). These mouth floor muscles become active during swallowing and cause tipping of the hyoid and elevation of the larynx. During swallowing, the elevation of the larynx becomes visible as a peak in the surface EMG signal. Figure 5.2 shows a normal swallowing movement: on the vertical axis the muscle activity (expressed in microvolts) is projected against the duration in seconds on the horizontal axis. One can see that during swallowing there is a brief period of muscle activity of the suprahyoid muscles. This causes the larynx to elevate during swallowing (Ding, 2002).

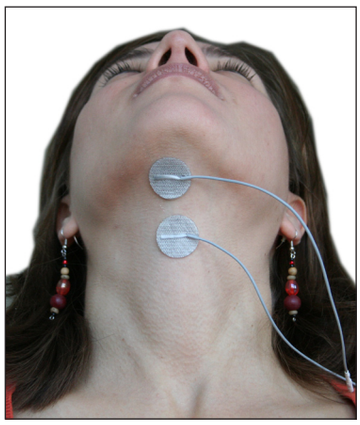

Figure 5.1
Position of the electrodes

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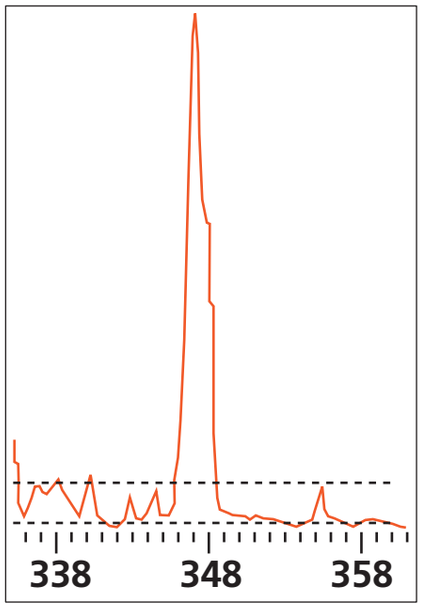

Figure 5.2
Normal swallowing movement

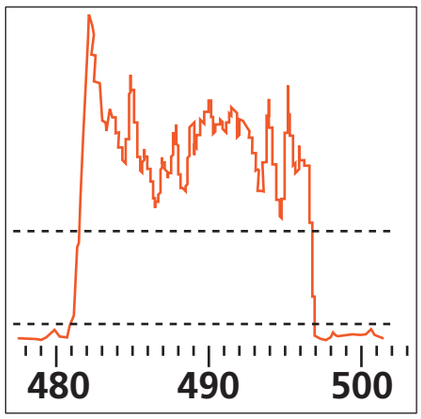

Figure 5.3
Mendelsohn maneuver

In the Mendelsohn maneuver the swallowing movement is influenced by tensing the suprahyoid muscles for several seconds. It is assumed that this will develop muscular strength, thus increasing the mobility of the larynx. With the aid of biofeedback, the patient can see not only that he can tighten these muscles for longer, but also how strongly he is tightening the muscles. Figure 5.3 shows the graph of a Mendelsohn maneuver: in comparison to Figure 5.2 one can see that the swallow continues for longer.

5.4. Indications and contraindications

Surface EMG as biofeedback can be used to supplement existing therapy in patients with swallowing problems in the pharyngeal phase of the swallowing movement. It is important that the patient is receptive to instructions and has a reasonable amount of stamina, as the exercises are often intensive and tiring. Good vision is essential for looking at a computer screen. Contraindications are neuromuscular disorders of a degenerative nature, as the intensive exercises will aggravate the swallowing problem. It is advisable to exercise restraint when using this treatment with patients who have a cardiac condition; as patients need to tense the neck muscles tightly, the blood pressure can rise. With patients with cardiac anamnesis it is advisable to consult the attending physician before commencing treatment.

5.5. Examples of the use of EMG biofeedback

This chapter describes four patients who were referred in connection with serious, persistent swallowing complaints after a Stroke at brainstem level. Table 5.1 describes the characteristics of these patients.

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Patient	Age	Months since infarction	Diagnosis with referral	Previous dysphagia treatment	Feeding status
1	59	5	Wallenberg syndroom	Yes, transfer	PEG tube
2	59	32	Lacunar infarction left side	Yes, finished treatment	Oral feeding
3	66	24	Lacunar infarction left side of brainstem	Yes, finished treatment	PEG tube
4	71	10	Wallenberg syndrome	Yes, finished treatment	PEG tube

Before referral, all four patients received extensive logopaedic treatment elsewhere for their swallowing problems. Only one patient had a moderate dysarthria, the other patients had no articulation problems. It could be argued that with these patients it is a matter of an isolated dysphagia.
One of the patients was referred by a rehabilitation centre for further logopaedic support. The other three patients had already finished logopaedic treatment elsewhere; the treatments were discontinued because effective results were not achieved.
With all four patients, exercises were carried out in the earlier logopaedic treatments, both on the basis of the functional logopaedic swallowing examination and on the basis of a swallowing video, that were aimed at improving the elements of swallowing that were most affected: larynx elevation and pharynx contraction. To this end, supraglottal swallowing, the Masako maneuver, the Mendelsohn maneuver and the Shaker head tilt exercise were practised. These exercises are described in detail in various publications (Logemann, 2000; Shaker, 1997; Fujiu, 1996).

All four patients were treated once a week for a maximum of one hour on an outpatient basis. The treatment was concluded when the patient could be fed completely orally again without problems.

The logopaedic treatment here consisted of intensive, repeated execution of the above exercises. Biofeedback was introduced during the Mendelsohn maneuver exercise to give the patient visual support with this exercise.

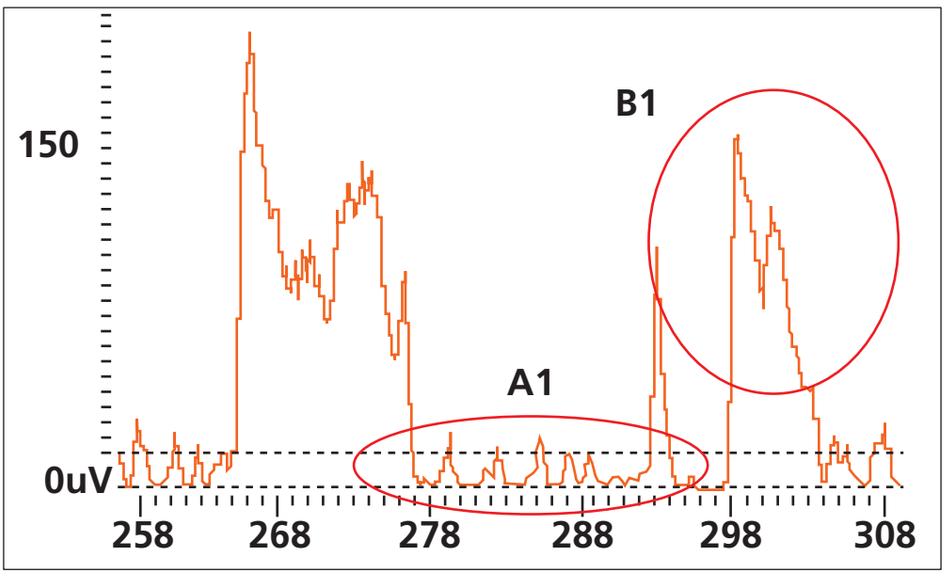

Figure 5.4
Patient 4, 1st treatment, Mendelsohn maneuver
A1 = excessive tongue movement to initiate swallowing movement
B1 = sharp drop in line shows reduction in muscle activity

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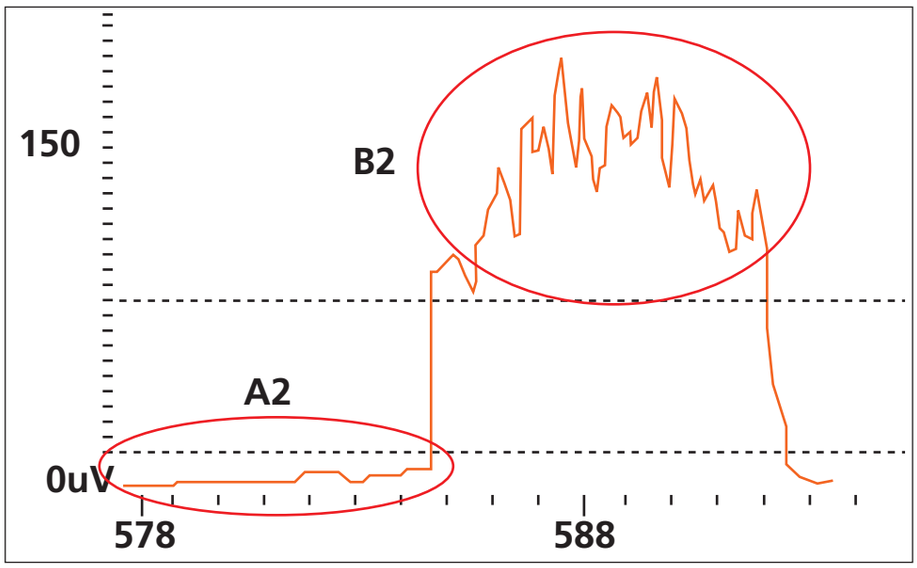

Figure 5.5
Patient 4, 5th treatment, Mendelsohn maneuver
A2 = more efficient swallowing effort
B2 = longer tensing of the muscles

As well as this outpatient treatment, the patients were asked to repeat these exercises at home three times daily for 20 minutes (without the use of surface EMG). With the home exercises the patients also carried out the Shaker head tilt exercise (Shaker, 1997).

Patient 1, patient 3 and patient 4 had to spit out their saliva into a container at the start of the treatment because they could not swallow it. During the therapy they had great difficulty with the swallowing movement; often it required a lot of energy and excessive tongue movements to swallow. This 'searching' for the swallowing effort is visible as irregular movements in the EMG signal (Figure 5.4, A1). With one patient there were clearly associated movements; this patient invariably squeezed his eyes shut each time he tried to swallow.
Also noticeable was that when they carried out the Mendelsohn maneuver the patients initially could not tighten the muscles for several seconds. The reduction in power is visible as a descending line on the EMG signal (Figure 5.4, B1).

5.6. Results

All four patients had fewer problems starting the swallowing movement after several weeks of treatment and spontaneous swallowing of saliva also occurred more frequently. This was mainly noticed because the patients' pillows were less wet in the mornings, while during the day they themselves (and those around them) noticed that they needed to spit out saliva less frequently; from this it was deduced in therapy that the spontaneous swallowing of saliva had evidently improved. At this point the oral intake for the three patients with a PEG tube was slowly increased: from ten spoonfuls of water with supraglottic pressure build-up, the intake of thin liquids was increased to about a cup of water or coffee per day. At the same time, careful swallowing of small quantities of thick liquid feeds (yogurt, custard) was started. After several sessions it became very clear in the biofeedback exercises that the patients needed to use less force to swallow and that there were fewer excessive (and associated) movements to initiate the swallowing movement (Figure 5.5, A2). The patients were also better able to coordinate the Mendelsohn maneuver and to maintain it for longer (Figure 5.5, B2). In the weeks that followed, the oral intake was slowly and gradually increased for all the patients and, where necessary and in consultation with the dietician, the quantity of tube feed was reduced. At the end of the treatment, all four patients were able to eat and drink without any problems (Table 5.2).

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Patient	Complaint at first dysphagia-treatment	Number of dysphagia treatments	Time between start and end of treatment	Feeding status after end of dysphagia treatment
1	no deglutition; spitting out saliva	7	57 days	full oral feeding, tube feeding reduced
2	choking on thin liquids, about 10 times a day; solid food remains stuck; fear of swallowing	5	56 days	no choking on thin liquids, eating all consistencies without problems
3	no deglutition; spitting out saliva	4	50 days	full oral feeding,tube feeding reduced
4	no deglutition; spitting out saliva; choking on saliva	6	63 days	full oral feeding, solid food still difficult

5.7. Discussion

All the patients treated had received logopaedic treatment before they started the therapy programme, without results. The results achieved with the biofeedback therapy can be called spectacular in this respect, particularly because in a number of patients no further progress had been expected, and it was assumed that they would be dependent on PEG tube feeding for the rest of their lives. As this involves a small group of patients, it raises a number of questions concerning possible explanations of the results. However, one justifiable question is which component from this treatment contributed most to the final result. As three of the four patients had completed their treatment, spontaneous recovery would not appear to play a role here. The average time between the infarction and the biofeedback treatment also refutes the possibility of spontaneous recovery.

In the case of two patients (1 and 4), it is known that they also did the Shaker head tilt exercise in the previous treatment, without the desired outcome. Although good results have been described with the Shaker head tilt exercise (Easterling, 1998), it would appear that in this case this exercise was not one of the most important factors in the recovery of the swallowing function. The Shaker head tilt exercise is aimed primarily at elevating the larynx and not at coordinating the swallowing movement and pharynx contraction (Bogaardt, 2002).

Another factor that may be significant is the intensity of the therapy. In all cases, the patients had previously practised at home, but not to the extent (20 minutes three times daily) prescribed in this programme. As this treatment concerns muscle training and coordination, it is likely that the intensity of treatment and training play a role; the number of patients is too small, however, to make a clear pronouncement in this case. No research has yet been carried out into the influence of treatment intensity in swallowing rehabilitation, but it may be assumed that in many cases only intensive treatment will give positive results.

The greatest difference between the therapy programme and the earlier, usual treatment is the use of surface EMG as biofeedback with the Mendelsohn maneuver.

5.8. Conclusion

As the results achieved in this patient series differ little from the results in other small-scale studies such as Stanschus (2002) and Crary (2005), it can be argued that there are good indications that the use of surface EMG as biofeedback for the treatment of chronic neurological swallowing problems has a positive effect on the duration and outcome of the treatment.

5.9. Literature

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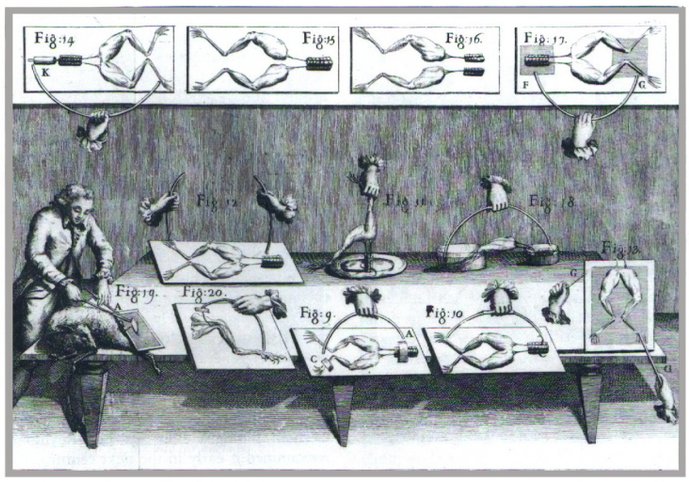
6. Neuromuscular electrostimulation for swallowing problems

6.1. Neuromuscular electrostimulation

Neuromuscular electrostimulation (NMES) is a method whereby muscles are stimulated by means of short electrical impulses. Since the 18th century it has been known that muscles contract under the influence of electricity. The first researcher who described this phenomenon was the founder of modern neurophysiology, Luis Galvani, who described the relationship between electricity and muscle activity in 1791. Galvani became well-known through his experiments, in which he demonstrated how frogs' legs contracted when they were stimulated with a current (see the illustration in a book by De Luca (1985) on



neurophysiology).
Figure 6.1
Galvani's experiments on frogs.

The principal of neuromuscular electrostimulation is based on the physiology of muscle activity. In a healthy person, muscles contract because an electrical impulse runs via various nerves from the cortex (central nerves) and via the spinal cord and peripheral nerves to the relevant muscle. This takes place in the case of conscious movements; with reflex activity there is no activity at the cortical level, but only electrical activity at the level of the peripheral nerves.

Figure 6.2 shows how various peripheral nerve fibres from the spinal cord are connected with the motor end plates in the muscles. A muscle does not contract because of the electrical activity itself, but because the electrical current at the end of the peripheral nerve causes a neurotransmitter to be emitted (acetylcholine). This acetylcholine binds to the muscle fibres and causes a depolarisation of the cell membranes of the muscle fibres, resulting in a so-called action potential. This action potential causes the contraction of the muscle fibres, so that the muscle contracts.

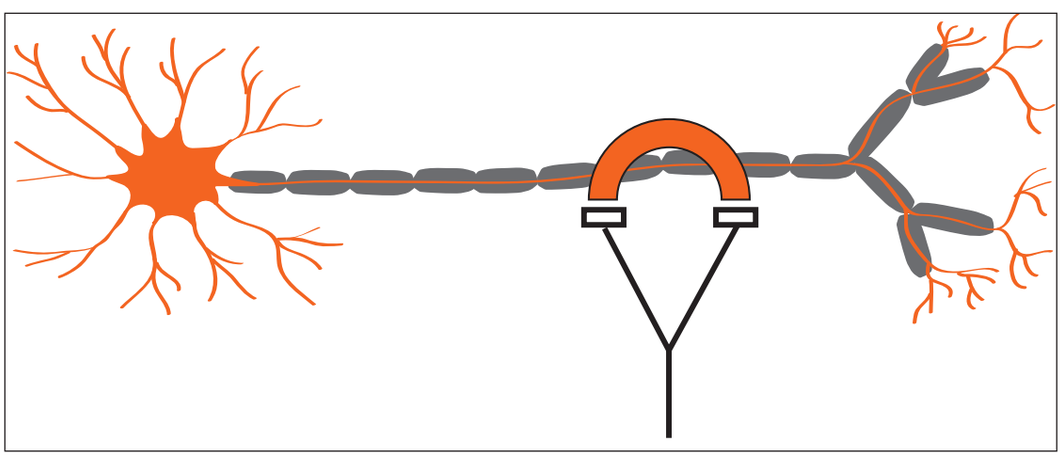


Figure 6.2
Peripheral nerve fibres

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In neuromuscular electrostimulation the peripheral nerve is stimulated by means of a device, for the purpose of contracting the whole muscle. The electrostimulation is achieved by placing two electrodes over the relevant nerve. One of the characteristics of a current is that the electron flow is from negative to positive. In neuromuscular electrostimulation, an alternating current is normally used, to create a continuous flow of electrons from one electrode to the other. This causes the electrons to flow through the muscle fibres of the underlying nerve, which is stimulated, so that the motor end plates release acetylcholine and the muscle eventually contracts. Figure 6.3 shows a diagrammatic overview of this form of electrostimulation.

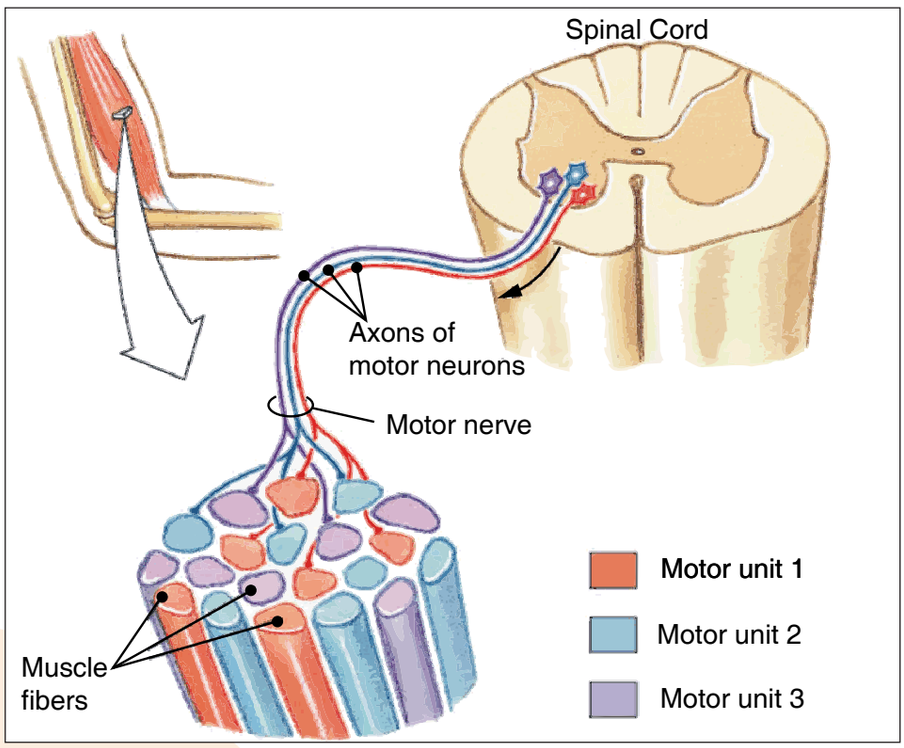

Figure 6.3
Neuromuscular electrostimulation

To stimulate a muscle or muscle group, it is important to know the parameters with which the human body itself stimulates these muscles. The description of an electrical current is generally based on frequency and phase duration. Figure 6.4 illustrates the different parameters of an electrical current.

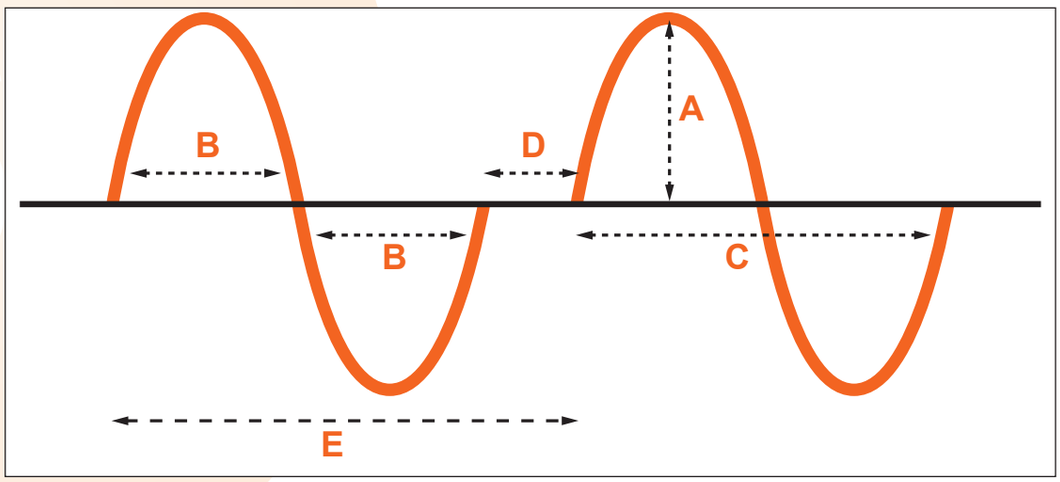

Figure 6.4.
Definitions of an electrical current

A = Amplitude
B = Phase duration
C = Pulse duration
D = Interpulse interval
E = Pulse period

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In order to treat swallowing problems with electrostimulation, it is important to know the characteristics (parameters) with which our own body controls the relevant swallowing muscles. The work of Doty and Bosma shows that the characteristics of the electrical current through the peripheral nerve to the larynx muscles are 200 µsec for the phase duration (B) with a stimulation frequency of 30 stimulations per second (= 30 Hz) (Doty, 1956). These parameters have therefore been used in this study into the effects of neuromuscular electrostimulation on swallowing function in patients with MS.

6.2. Treatment and effectiveness

In 2001, Vanderthommen and Crielaard stated that NMES is frequently used in physiotherapy to strengthen healthy muscles. They also state that NMES is regularly used in the treatment of atrophied muscles. This achieves good results if the NMES takes place at the same time as specific muscle exercises. These researchers state that this combination is more beneficial than traditional treatment without NMES (Vanderthommen, 2001).

In 2003, Smith et al used functional MRI to determine the relationship between the dose (intensity) and the results of treatments with NMES. This study shows that more cortical activity can also be measured with peripheral stimulation, but it is stated hypothetically that NMES works not only at the peripheral (muscle) level, but that this treatment can also cause changes centrally in the brain. Researchers conclude that their findings could provide a new stimulus for further research (Smith, Alon et al. 2003). Following this, Umarova et al. published a study in 2005, in which they demonstrate that no increase in brain activity is seen in acute Stroke patients being treated with NMES, but that the motor functions of the patients recovered faster than in the control group (Umarova, 2005).

It can be concluded that in the literature, the effectiveness of NMES in terms of faster training of muscles and muscle groups has been demonstrated and the discussion is inclined towards a discussion of whether NMES, apart from motor training, also has a sensory component that may have a positive effect on the cortex.

6.3. Neuromuscular electrostimulation: treatment of swallowing problems

Freed (2001) was the first to publish details of a therapy programme for patients with swallowing problems in which NMES was used. In this programme, the supralaryngeal muscles were trained with the aid of an electrostimulator (Freed, 2001). The purpose of the electrostimulator is to stimulate the muscles responsible for lanyngeal elevation during swallowing. Two muscles (muscle groups) are stimulated: the m thyrohyoideus and the mouth floor muscles (incl. m. digastricus). The m. thyrohyoideus runs between the tongue bone (hyoid) and the thyroid cartilage of the larynx (thyroid) and with contraction during swallowing causes vertical elevation of the larynx . The mouth floor muscles cause an anterior (forward) movement of the hyoid during swallowing, so that during swallowing the larynx also moves forward and causes the top oesophagus sphincter to open (Ding, 2002).

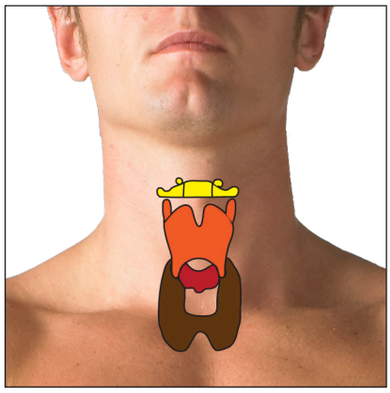

Figure 6.5
anatomical structures.

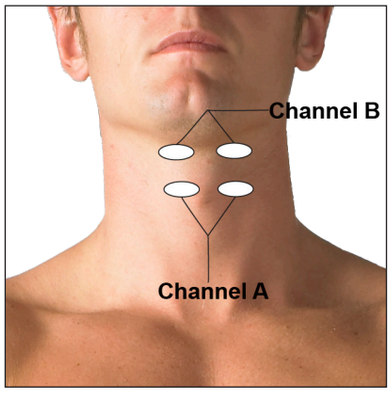

Figure 6.6
The positions of the electrodes

The use of electrostimulation in the treatment of dysphagia is, as stated, relatively new in logopaedics; consequently, there is a scarcity of literature on the effectiveness of this form of treatment. Furthermore, the treatment is not undisputed (Logemann, 2007), because the small amount of research that has been carried out into the effectiveness of NMES for swallowing problems is often of mediocre quality.

Following the Freed study in 2001, a study by Leelamanit in 2003 also shows positive effects on swallowing function in patients (Leelamanit, 2002). However, this study leaves many methodological questions unanswered and it is not clear with which parameters the researchers stimulated their patients.
A study by Burnett, published in 2003, examined the extent to which larynx elevation could be facilitated by electrical stimulation by means of needle electrodes in the mouth floor muscles. Muscles including the m digastricus were stimulated in 15 healthy test subjects at 30 Hz and 200 µsec. It was observed that

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in this way (without deglutition) the larynx achieves about 50% of maximum elevation during deglutition. This study concludes that during swallowing electrostimulation may be a valuable contribution in swallowing rehabilitation (Burnett, 2003)
In a more recent study, the results of 40 patients with swallowing problems who were treated with NMES were compared with the results of 40 patients with swallowing problems who were treated according to conventional methods. This study shows that the treatment of swallowing problems with NMES is superior to conventional logopaedic treatment (Blumenfeld, 2006). In this study, American equipment was used, with stimulation parameters of 80 Hz and 300 µsec, which may not be optimal muscle stimulation. Almost at the same time, however, a study was published (Kiger, 2006) in which 22 patients with swallowing problems were randomised into two groups: one group was treated with NMES and the other without NMES. In this study, no significant differences were found in the outcomes. As a criticism of this study it may be stated that the two small groups (N=11) may have led to an underpowered study and the question is whether investigators can draw hard conclusions from such a small trial.
The number of speech therapists using this type of treatment is increasing worldwide (Logemann, 2007). Future studies in this field must be aimed at determining the correct stimulation parameters and determining the correct treatment intensity.

6.4. Indications and contraindications

Neuromuscular electrostimulation can be used in combination with exercises to strengthen the muscles in the neck area. The treatment is aimed at patients with problems in the pharyngeal phase of deglutition, in which a significant component of the swallowing problem is reduced muscle strength.
Important contraindications for this application include: patients with a cardiac pacemaker, patients with skin infections (in connection with the electrodes), patients with possible neoplasmata (consultation with attending physician is necessary in this case) and patients with metal implants in the treatment area. When placing electrodes on the skin, the therapist must ensure that they are not placed on the large blood vessels in the neck, as this may restrict the blood flow to the brain.

Despite these contraindications, neuromuscular electrostimulation has been used by increasing numbers of therapists in recent years to treat swallowing problems. As a result of good instruction and supervision, no serious problems have occurred in terms of side effects and accidents.

Caution:

The use of neuromuscular stimulation in the head-neck area is not without risk!

This treatment must only be used after thorough instruction. Untrained use of this application can cause injury to the patient!

6.5. Example of the use of neuromuscular electrostimulation

Mr A. is a 64-year-old man who twice experienced a cerebral infarction. The first was an infarction in the brain stem, nearly four years ago, and the second an infarction of the arteria cerebri media, over a year ago. The patient had previously received logopaedic therapy in a hospital, rehabilitation centre and nursing home, without recovery of the swallowing function.

The patient experienced a number of episodes of aspiration pneumonia, has a PEG tube and cannot eat or drink anything. In the first instance, the saliva aspiration is treated with scopolamine plasters, but this does not have any effect on the aspiration of saliva and the patient has reported considerable side effects of this medication. When the swallowing movement is evaluated using flexible endoscopy, what is noticeable is the large degree of saliva aspiration (see Figure 6.7). With video fluoroscopy, strong aspiration is also seen with thin and thick liquids. In the case of thick liquids it was very clear that after swallowing a lot of material remained in the throat and that thick liquids were also being aspirated.

It was agreed to start treatment with neuromuscular electrostimulation.

Figure 6.7
Before treatment (flexible endoscopy): Continuous overflow of saliva to the trachea

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The treatment consisted of twelve sessions with NMES for four weeks; the patient received two treatments of 15 to 20 minutes in one hour, three times a week. The electrodes were positioned on the neck, as illustrated in Figure 6.6. The level of stimulation was set so that the patient had the feeling that the muscles in the neck were tensed. This was about 80% of the stimulation level that was uncomfortable for the patient. During the treatment, the patient was asked to swallow forcefully once every 30 seconds. Every five minutes during the treatment, the patient was asked if he still felt the electrostimulation and if this was not the case, the stimulation was increased without the patient feeling any pain.

After twelve treatments, another swallowing video and a flexible endoscopy were carried out to determine the swallowing function. Figure 6.8 shows that there is no longer any stasis of saliva in the pharynx, which is a clear improvement in comparison with the situation before the start of the treatment (see Figure 6.7). The swallowing video also showed a clear improvement; minimal aspiration was seen only with swallowing 10 ml of thin liquid contrast medicine; with smaller quantities there was no choking. Swallowing thick liquids also appeared to have improved: there was no longer any (tendency to) aspiration, and after swallowing there was no appreciable residue in the throat.

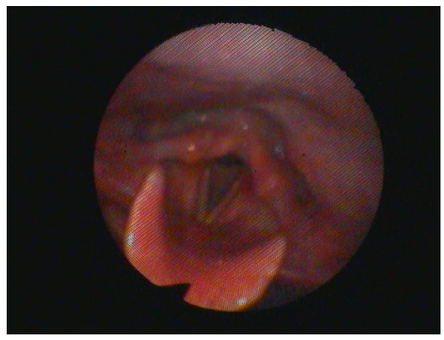

Figure 6.8
After treatment (flexible endoscopy): No saliva stasis, no saliva aspiration

On the basis of the investigation, it was advised to start careful oral feeding, only swallowing very small quantities of thin liquids (up to 5 ml). With larger quantities of liquids it was advised to thicken this with a thickening agent. After three months the PEG tube was removed.

6.6. Example of use of a combination of EMG and NMES

Mr B. is a 58-year-old man, who one year ago had subarachnoidal bleeding from an aneurism of the a. vertebralis. Progress was initially extremely complicated, including development of hydrocephalus and meningitis. Eventually there was a good recovery; the patient is fully mobile, but has swallowing problems and a slight inability to concentrate. The patient is fed completely orally and does not require any tube feeding.
The patient said that in principle he can eat anything he wants, but that when he is eating, solid food remains hanging in the throat. This means that he has to drink a lot of water during the meal, and it also interferes with his social contacts. Earlier logopaedic supervision had allowed the patient to eat and drink again after hospital discharge, but the above problems remained.

With flexible endoscopy, a reduced pharynx contraction can be seen on the left side, although the swallowing function appears to be unaffected. The reduced contraction of the pharyngeal muscles is seen as the cause of the passage disorder.

During the treatment, surface EMG is used as biofeedback. The swallowing function is explained to the patient and the swallowing is visualised on the screen with the aid of the equipment. After this, the Mendelsohn maneuver is practised for half an hour (see paragraph 4.5), and the patient is asked to do the exercise in such a way that during the Mendelsohn maneuver the EMG signal is at around 75% of the maximum amplitude during swallowing. This proved to be a fairly intensive and tiring exercise for the patient, but he was soon able to perform it well. At the end of the first treatment, the patient was instructed to do the same exercise 20 times, three times a day, at the same intensity. The patient returned for outpatient treatment, using NMES three more times the following month. The electrodes were placed on the skin as in Figure 5.5 with half stimulation. The patient was asked to make a Mendelsohn maneuver for 10 seconds every 30 seconds.

After two treatments, the patients already reported that for the first time he could eat an apple again, without needing to drink any water with it to remove remnants from the throat.
At the end of the treatments, the patient reported that less food remained in the throat during eating. He now needs to drink less water during meals and he is able to eat more quickly. Sometimes, after a longer meal, some food does remain stuck in the throat. He reports that he continues to practise three times a day, with 15 repetitions of the Mendelsohn maneuver on each occasion.
He will slowly cut this back and if the swallowing problems recur, he knows which exercises he needs to do. The patient is pleased with the result of the treatment and no further appointments are necessary.

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6.7. Literature

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7. Treatment programmes and protocols

This chapter describes two protocols for the treatment of swallowing problems with the Myomed 134 as a stand-alone device. The device is not connected to a computer.
It is possible to connect the Myomed to a computer and to set it up on the computer, and this is recommended when using EMG biofeedback with older patients and patients with reduced vision, as the screen is larger.
Please refer to the instructions enclosed with the software; the principal is the same as that described below.

7.1. EMG-biofeedback

7.1.1. Positioning the electrodes

1. Connect two electrodes (+ and –) under the chin. Use channel 1 on the Myomed 134 for this: the black and the red outputs. Make sure to fit the front electrode just behind the chin and the other electrode in a straight line about once centimetre behind it.
2. Connect the reference electrode to the green output of the Myomed 134 and position the electrode on the patient's neck or on the cheek.

7.1.2. Visualisation of the swallowing movement

1. Start the Myomed 134
2. Select EMG
3. Select Continue
4. Select Treatment time and set it to 30:00 (= 30 minutes)
5. Select Graph and set it at Curve
6. Press Start
7. Demonstrate how the device reacts to movement of the tongue: e.g. when sticking out the tongue, a curve is displayed.
8. Ask the patient to swallow and point out the curve (peak amplitude)
9. Note the peak amplitude of a normal swallow (in order to set the threshold for further treatment)
10. Ask the patient to make a 'long swallow' of 8 to 10 seconds every 30 seconds (Mendelsohn maneuver), and to make the curve as high as possible

When the patient can control this well and understands the principle of the biofeedback, another feature of the Myomed can be used: work/rest cycles.

Stop the programme and return to the Main menu.

7.1.3. Using the work/rest cycles

Explain to the patient that he will be doing the same swallowing movements, but that they will be interspersed with 20-second rest periods between 'long' swallow movements. The patient will first see a diagram of a man sleeping on a bed on the screen; this is the rest period. This is followed by a weightlifter, and when the patient hears a bleep he has to make a long swallow and try to maintain this until the next bleep (after 10 seconds).
In the centre of the display there is a horizontal line, set at 75% (or lower during the initial sessions) of the maximum muscle activity in normal swallowing. The patient must try to swallow forcefully enough to bring the curve above this line.

Note:
If this is too difficult for the patient during the initial therapy sessions, the Threshold can be set at a lower level and raised at the next session. This will stimulate the patient to train the muscles harder.

1. Select EMG
2. Select Work / rest
3. Select Rest time and set it at 20 seconds
4. Select Work time and set it at 10 seconds
5. Select Cycles and set this at 30 (= 15 minutes treatment time)
6. Select EMG threshold 1 and set it at 75% of the peak amplitude of the normal swallow (see above)
7. Select Graph and set it at Curve
8. Press Start

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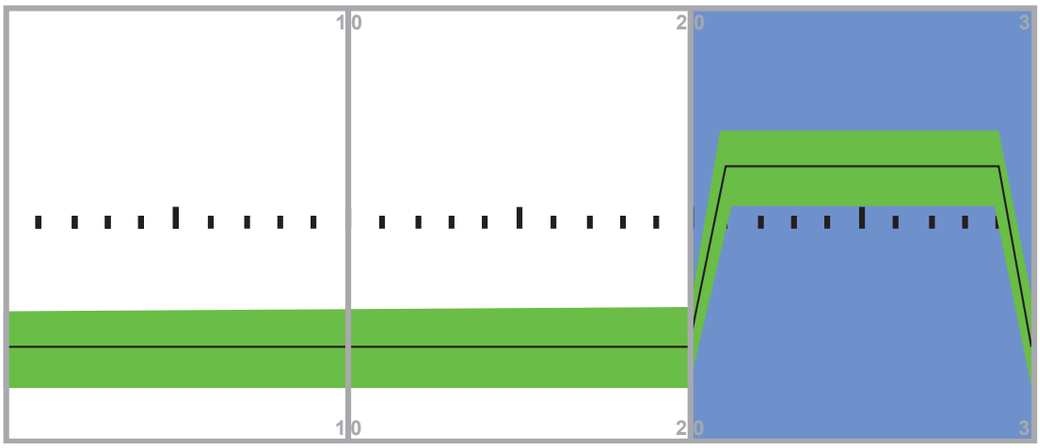

7.2. Neuromuscular electrostimulation

7.2.1. Positioning the electrodes

1. Palpate the neck and locate the thyroid and the hyoid.
2. Place two small electrodes between the thyroid and the hyoid, both about once centimetre from the centre line, i.e. one on each side of the centre line.
3. Connect the electrodes to output 2 of the Myomed 134
4. Palpate the mouth floor and locate the jaw bone and the hyoid.
5. Place the two electrodes beside each other under the mouth floor, halfway between the hyoid and the chin
6. Connect these electrodes to output 1 of the Myomed 134

7.2.2. Setting up neuromuscular electrostimulation

1. Start the Myomed 134
2. Select Stimulation
3. Select Treatment time and set it at 20:00 (=20 minutes)
4. Select Graph and set it at Curve
5. Select Phase duration and set it at 200 µs
6. Select Frequency and set it at 30 Hz
7. Select Swell pattern and select Yes
8. Select Swell rise time and set it at 1.0 s
9. Select Hold time and set it at 5 seconds
10. Select Swell decrease and set it at 0.1 s
11. Select Interval time and set it at 20 s

Explain to the patient that he will shortly feel a tingling sensation under the chin.

12. Select Current1

The patient will first feel a tingling sensation, which changes to a feeling as if someone is grabbing him by the throat, and with further stimulation it becomes painful for the patient. Explain this to the patient. Slowly increase the current and stop when it becomes painful for the patient.
A motor response of the muscles is normally achieved when the current intensity is about 70% to 80% of the level at which it is painful for the patient. This motor response (the feeling that someone is taking hold of the muscles) is the required level of stimulation

13. Select Current2 and slowly turn it up.

The patient will now feel a similar sensation on the throat. Once again slowly increase the stimulation until the patient has the feeling that someone is grabbing him by the throat.

The settings for electrostimulation are now optimal.

14. Explain to the patient that he will shortly feel the current and that he must then swallow forcefully (make a Mendelsohn maneuver). Explain that the stimulation will only last for a few seconds and will then fade. This is followed by 20 seconds without stimulation. As soon as the patient feels the current rising again he has to swallow again.

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15. Press Start

Note:
If the patient is able to make Mendelsohn maneuvers, it is advisable to set the Hold time at 10 seconds instead of 5 seconds.

8. Recommended literature

Below are abstracts of various articles on the use of EMG biofeedback and on the use of electrostimulation in the treatment of dysphagia. This literature is recommended for therapists who want to read further background information and inform themselves about the latest scientific developments in this field.

8.1. EMG biofeedback and swallowing problems

- *Crary MA, Carnaby Mann GD, Groher ME, Helseth E. Functional benefits of dysphagia therapy using adjunctive sEMG biofeedback. Dysphagia. 2004 Summer;19(3):160-4.*

  This article describes a retrospective analysis of functional outcome, time in therapy, and cost per unit of functional change in patients who received therapy for pharyngeal dysphagia. Twenty-five patients presenting dysphagia following stroke and 20 patients with dysphagia following treatment for head/neck cancer completed a systematic therapy program supplemented with surface electromyographic (sEMG) biofeedback. Eighty-seven percent (39/45) of all patients increased their functional oral intake of food/liquid including 92% of stroke patients and 80% of head/neck cancer patients. Patients with dysphagia following stroke demonstrated greater improvement than those in the head/neck cancer group. Patients in the stroke group completed more therapy sessions thus increasing the total cost of therapy, but they made more functional progress resulting in lower costs per unit of functional change than patients in the head/neck cancer group. Limitations of this study are described in reference to implications for future clinical research on the efficacy of this therapy approach.

- *Huckabee ML, Cannito MP. Outcomes of swallowing rehabilitation in chronic brainstem dysphagia: A retrospective evaluation. Dysphagia. 1999 Spring;14(2):93-109.*

  This study examines the functional and physiologic outcomes of treatment in a group of 10 patients with chronic dysphagia subsequent to a single brainstem injury. All patients participated in a structured swallowing treatment program at a metropolitan teaching hospital. This program differs from more traditional swallowing treatment by the inclusion of surface electromyography biofeedback as a treatment modality and the completion of 10 hr of direct treatment in the first week of intervention. A retrospective analysis of medical records and patient questionnaires was used to gain information regarding medical history, site of lesion, prior interventions, and patient perception of swallowing recovery. Physiologic change in swallowing treatment, as measured by severity ratings of videofluoroscopic swallowing studies, was demonstrated in nine of 10 patients after 1 week or 10 sessions of treatment. Functional change was measured by diet level tolerance after 1 week of treatment, at 6 months, and again at 1 year post treatment. Eight of the 10 patients were able to return to full oral intake with termination of gastrostomy tube feedings, whereas two demonstrated no long-term change in functional swallowing. Of the eight who returned to full oral intake, the average duration of tube feedings following treatment until discontinuation was 5.3 months, with a range of 1-12 months. Six patients who returned to oral intake maintained gains in swallowing function, and two patients returned to non oral nutrition as the result of a new unrelated medical condition.

8.2. Electrostimulation and swallowing problems

- *Freed ML, Freed L, Chatburn RL, Christian M. Electrical stimulation for swallowing disorders caused by stroke. Respir Care. 2001 May;46(5):466-74.*

  An estimated 15 million adults in the United States are affected by dysphagia (difficulty swallowing). Severe dysphagia predisposes to medical complications such as aspiration pneumonia, bronchospasm, dehydration, malnutrition, and asphyxia. These can cause death or increased health care costs from increased severity of illness and prolonged length of stay. Existing modalities for treating dysphagia are generally ineffective, and at best it may take weeks to months to show improvement. One common conventional therapy, application of cold stimulus to the base of the anterior faucial arch, has been reported to be somewhat effective. We describe an alternative treatment consisting of transcutaneous electrical stimulation (ES) applied through electrodes placed on the neck. OBJECTIVE: Compare the effectiveness of ES treatment to thermal-tactile stimulation (TS) treatment in patients with dysphagia caused by stroke and assess the safety of the technique. METHODS: In this controlled study, stroke patients with swallowing disorder were alternately assigned to one of the two treatment groups (TS or ES). Entry criteria included a primary diagnosis of stroke and confirma-

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tion of swallowing disorder by modified barium swallow (MBS). TS consisted of touching the base of the anterior faucial arch with a metal probe chilled by immersion in ice. ES was administered with a modified hand-held battery-powered electrical stimulator connected to a pair of electrodes positioned on the neck. Daily treatments of TS or ES lasted 1 hour. Swallow function before and after the treatment regimen was scored from 0 (aspirates own saliva) to 6 (normal swallow) based on substances the patients could swallow during a modified barium swallow. Demographic data were compared with the test and Fisher exact test. Swallow scores were compared with the Mann-Whitney U test and Wilcoxon signed-rank test. RESULTS: The treatment groups were of similar age and gender ($p > 0.27$), co-morbid conditions ($p = 0.0044$), and initial swallow score ($p = 0.74$). Both treatment groups showed improvement in swallow score, but the final swallow scores were higher in the ES group ($p > 0.0001$). In addition, 98% of ES patients showed some improvement, whereas 27% of TS patients remained at initial swallow score and 11% got worse. These results are based on similar numbers of treatments (average of 5.5 for ES and 6.0 for TS, $p = 0.36$). CONCLUSIONS: ES appears to be a safe and effective treatment for dysphagia due to stroke and results in better swallow function than conventional TS treatment.

- *Blumenfeld L, Hahn Y, Lepage A, Leonard R, Belafsky PC. Transcutaneous electrical stimulation versus traditional dysphagia therapy: a non concurrent cohort study. Otolaryngol Head Neck Surg. 2006 Nov;135(5):754-7*

  OBJECTIVE: The purpose of this investigation was to critically evaluate the efficacy of electrical stimulation (ES) in treating persons with dysphagia and aspiration. STUDY DESIGN: Non concurrent cohort study. METHODOLOGY: The charts of 40 consecutive individuals undergoing ES and 40 consecutive persons undergoing traditional dysphagia therapy (TDT) were reviewed. Pre- and post-therapy treatment success was compared utilizing a previously described swallow severity scale. A linear regression analysis was employed to adjust for potential confounding variables. RESULTS: The swallow severity scale improved from 0.50 to 1.48 in the TDT group ($P < 0.05$) and from 0.28 to 3.23 in the ES group ($P < 0.001$). After adjusting for potential confounding factors, persons receiving ES did significantly better in regard to improvement in their swallowing function than persons receiving TDT ($P = 0.003$). CONCLUSIONS: The results of this non concurrent cohort study suggest that dysphagia therapy with transcutaneous electrical stimulation is superior to traditional dysphagia therapy alone in individuals in a long-term acute care facility.

- *Kiger M, Brown CS, Watkins L. Dysphagia Management: An Analysis of Patient Outcomes Using VitalStim Therapy Compared to Traditional Swallow Therapy. Dysphagia. 2007 Jan 10; [Epub ahead of print]*

  This study compares the outcomes using VitalStimtrade mark therapy to outcomes using traditional swallowing therapy for deglutition disorders. Twenty-two patients had an initial and a followup videofluoroscopic swallowing study or fiberoptic endoscopic evaluation of swallowing and were divided into an experimental group that received VitalStim treatments and a control group that received traditional swallowing therapy. Outcomes were analyzed for changes in oral and pharyngeal phase dysphagia severity, dietary consistency restrictions, and progression from nonoral to oral intake. Results of chi(2) analysis showed no statistically significant difference in outcomes between the experimental and control groups.

- *Ludlow CL, Humbert I, Saxon K, Poletto C, Sonies B, Crujido L. Effects of Surface Electrical Stimulation Both at Rest and During Swallowing in Chronic Pharyngeal Dysphagia. Dysphagia. 2006 May 23; [Epub ahead of print]*

  We tested two hypotheses using surface electrical stimulation in chronic pharyngeal dysphagia: that stimulation (1) lowered the hyoid bone and/or larynx when applied at rest, and (2) increased aspiration, penetration, or pharyngeal pooling during swallowing. Bipolar surface electrodes were placed on the skin overlying the submandibular and laryngeal regions. Maximum tolerated levels of stimulation were applied while patients held their mouth closed at rest. Videofluoroscopic recordings were used to measure hyoid movements in the superior-inferior and anterior-posterior dimensions and the subglottic air column position while stimulation was on or off. Patients swallowed 5 ml liquid when stimulation was off, at low sensory stimulation levels, and at maximum tolerated levels (motor). Speech pathologists, blinded to condition, tallied the frequency of aspiration, penetration, pooling, and esophageal entry from videofluorographic recordings of swallows. Only significant ($p = 0.0175$) hyoïd depression occurred during stimulation at rest. Aspiration and pooling were significantly reduced only with low sensory threshold levels of stimulation ($p = 0.025$) and not during maximum levels of surface electrical stimulation. Those patients who had reduced aspiration and penetration during swallowing with stimulation had greater hyoid depression during stimulation at rest ($p = 0.006$). Stimulation may have acted to resist patients' hyoid elevation during swallowing.

- *Burnett TA, Mann EA, Cornell SA, Ludlow CL. Laryngeal elevation achieved by neuromuscular stimulation at rest. J Appl Physiol. 2003 Jan;94(1):128-34*

  During swallowing, airway protection is achieved in part by laryngeal elevation. Although multiple muscles are normally active during laryngeal elevation, neuromuscular stimulation of select muscles was evaluated to determine which single muscle or muscle pair best elevates the larynx and should

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be considered during future studies of neuromuscular stimulation in dysphagic patients. Hooked-wire monopolar electrodes were inserted into mylohyoid, thyrohyoid, and geniohyoid muscle regions in 15 healthy men selected for having a highly visible thyroid prominence for videotaping. During trials of single, bilateral, and combined muscle stimulations, thyroid prominence movements were video recorded, digitized, and normalized relative to elevation during a 2-ml water swallow. Individual muscle stimulation induced approximately 30% of the elevation observed during a swallow and approximately 50% of swallow velocity, whereas paired muscle stimulation resulted in approximately 50% of the elevation and approximately 80% of the velocity produced during a swallow. Paired muscle stimulation produced significantly greater elevation than single muscle stimulation and could assist with laryngeal elevation in dysphagic patients with reduced or delayed laryngeal elevation.

- *Burnett TA, Mann EA, Stoklosa JB, Ludlow CL. Self-triggered functional electrical stimulation during swallowing. J Neurophysiol. 2005 Dec;94(6):4011-8. Epub 2005 Aug 17.*

  Hyolaryngeal elevation is essential for airway protection during swallowing and is mainly a reflexive response to oropharyngeal sensory stimulation. Targeted intramuscular electrical stimulation can elevate the resting larynx and, if applied during swallowing, may improve airway protection in dysphagic patients with inadequate hyolaryngeal motion. To be beneficial, patients must synchronize functional electrical stimulation (FES) with their reflexive swallowing and not adapt to FES by reducing the amplitude or duration of their own muscle activity. We evaluated the ability of nine healthy adults to manually synchronize FES with hyolaryngeal muscle activity during discrete swallows, and tested for motor adaptation. Hooked-wire electrodes were placed into the mylo- and thyrohyoid muscles to record electromyographic activity from one side of the neck and deliver monopolar FES for hyolaryngeal elevation to the other side. After performing baseline swallows, volunteers were instructed to trigger FES with a thumb switch in synchrony with their swallows for a series of trials. An experimenter surreptitiously disabled the thumb switch during the final attempt, creating a foil. From the outset, volunteers synchronized FES with the onset of swallow-related thyrohyoid activity (approximately 225 ms after mylohyoid activity onset), preserving the normal sequence of muscle activation. A comparison between average baseline and foil swallows failed to show significant adaptive changes in the amplitude, duration, or relative timing of activity for either muscle, indicating that the central pattern generator for hyolaryngeal elevation is immutable with short term stimulation that augments laryngeal elevation during the reflexive, pharyngeal phase of swallowing.

- *Bogaardt HCA, van Dam D, Wever NM, Bruggeman C, Koops J, Fokkens WJ. Efficacy of neuromuscular electrostimulation in the treatment of dysphagia in patients with multiple sclerosis. 2007 (submitted manuscript)*

  Twenty five patients (avg. age 53.1; SD± 9.8) with multiple sclerosis and swallowing problems were treated for three weeks with two sessions of neuromuscular electrostimulation (NMES) per week. Average time since onset of multiple sclerosis was 16.5 (SD±10.2) years.
  For neuromuscular electrostimulation a Myomed 134-electrostimulator (ENRAF-NONIUS) was used. Stimulation parameters were set at 30 Hz with a phase duration of 200 µsec, with a surge pattern. Ramp-up time was 0.5 second, hold time 5 seconds and ramp-down time of 0.1 second. Two sets of electrodes (Valutrode) were used: one set was placed to stimulate the floor of mouth muscles and one set to stimulate the m. thyrohyoideus.
  After treatment a significant decrease in pooling of saliva in the piriform sinuses was seen ($p=0.03$) and significant less aspiration during the swallowing of thin liquids ($p<0.01$). Overall patients reported that their swallowing had improved ($p<0.01$) and in 20% of all patients had become less strenuous. No adverse effects of the treatment were reported. We conclude that the treatment of swallowing problems in patients with multiple sclerosis is effective.

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