Chapter 6
Electrical Stimulation for the Treatment of Dysphagia

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Abstract Dysphagia is the term used to describe swallowing disorders usually resulting from a neurological or physical impairment of the oral, pharyngeal or oesophageal mechanisms. Difficulty with swallowing may have life threatening consequences and can lead to an impaired quality of life. Electrical stimulation has recently become of interest to clinicians working with people presenting with dysphagia due to its rehabilitation potential especially for pharyngeal stage swallowing disorders. The electrotherapies for dysphagia can be divided into two main groups; those that are peripherally delivered and those where the stimulation is delivered cortically. This chapter outlines a number of electro-therapies as treatment approaches for dysphagia. The rationale for the use of each technique in the treatment of dysphagia is explained and an overview of the current published literature reported.

Keywords Dysphagia • Electrical stimulation • Electro-therapies • Neuro-muscular electrical stimulation • Repetitive transcranial magnetic stimulation

Introduction

Dysphagia is the term used to describe a swallowing disorder usually resulting from a neurological or physical impairment of the oral, pharyngeal or oesophageal mechanisms. The significance of dysphagia has only relatively recently been appreciated. It has a marked impact on survival, general health and quality of life. There are a

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range of approaches to the assessment of dysphagia which is important given that aspiration (food or liquid entering the lungs) as a result of impaired swallowing can be easily overlooked, and if untreated may result in the person developing pneumonia. The most significant method of improving dysphagia is by detecting its presence, nature and severity through appropriate assessment. Without this, appropriate interventions cannot be implemented and, conversely inappropriate interventions may not be avoided.

Dysphagia can be a transient, persistent or a progressively worsening symptom according to the underlying pathology. The normal swallow has four interconnected physiological phases:

1. oral preparatory phase
2. oral phase
3. pharyngeal phase
4. oesophageal phase

The first three of these together are termed the oropharyngeal phase [1]. The 'normal' swallow needs the respiratory, oral, pharyngeal, laryngeal and oesophageal anatomical structures to function in synchrony, which is dependent upon the cognitive, motor and sensory nervous system being intact. Disorders of swallowing are associated with increased likelihood of aspiration, chest infections, and under nutrition. Pneumonia is common sequelae of dysphagia and is associated with higher costs of care [2].

Incidence and Prevalence of Dysphagia

Disordered swallowing has been recognised as a significant problem following stroke. Whilst stroke is the third most common cause of death and the most important cause of long-term disability most stroke-related deaths are due to medical complications of the stroke, rather than directly due to the neurological damage. Only 10% of stroke-related deaths are caused by neurological deficits, while 30% of post-stroke deaths are due to pneumonia [3]. In 67% of patients pneumonia manifests within 48 h of admission [4]. Clinical studies show evidence of dysphagia in over 70% of stroke patients [5]. In 75% of patients with early swallowing problems dysphagia will continue to be moderate to severe, and in 15% it will remain profound [6]. Preventing pneumonia with early and effective treatment of dysphagia could have a significant impact on survival, patient experience, functional recovery and costs.

Dysphagia is a common symptom associated with progressive neurological disease with 200/100,000 UK population having difficulties with swallowing associated with Parkinson's disease [7]. Furthermore, more than 90% of those with motor neurone disease (ALS) will develop this symptom at some point in the course of the disorder. Sixty-eight percent of those with dementia in nursing homes have been reported as having difficulty swallowing and this is considered a low estimate [8].

Suckling and swallowing are common problems associated with cerebral palsy (57 and 38%) in the first 12 months of life [9].

Dysphagia is, also, now recognised as a symptom of concern in many other conditions such as COPD [10], head and neck cancer [11], thermal burn injury [12] and acquired brain injury [13]. A study of those having cervical discectomy and fusion indicated an incidence of dysphagia in 50.3% of patients [14].

Impact of Dysphagia

Dysphagia can present in many ways, and the patient may demonstrate one or several of the following symptoms:

- Food spillage from lips
- Taking a long time to finish a meal
- Poor chewing ability
- Dry mouth
- Drooling
- Nasal regurgitation
- Food sticking in the throat
- Poor oral hygiene
- Coughing and choking
- Regurgitation
- Weight loss
- Repeated chest infections

Difficulty with swallowing may have life threatening consequences and can lead to an impaired quality of life. This may be due to embarrassment and lack of enjoyment of food, which can have profound social consequences for both the person and members of the family.

Role of the Speech and Language Therapist in the Management of Dysphagia

Speech and language therapists/speech pathologists have a unique role in the assessment, diagnosis and management of oropharyngeal dysphagia. The aims and objectives of speech and language therapy interventions for dysphagia depend on the type and nature of the dysphagia, the underlying cause, and the needs and preferences of the individual. Considering the safety of the swallow, managing aspiration and preventing complications are of paramount concern. In children the aims and objectives will change as appropriate to the age as the child's anatomy and neurological abilities alter with growth and development [15].

The overall aims of the speech and language therapist working with an individual with dysphagia include:

- accurate assessment (there may be multiple assessments over time) leading to accurate diagnosis of dysphagia which may assist with the differential medical diagnosis.
- ensuring safety (reducing or preventing aspiration) with regards to swallowing function.
- balancing these factors with quality of life, taking into account the individual's preferences and beliefs.
- working with other members of the team, particularly dieticians, to optimise nutrition and hydration.
- stimulating improved swallowing with oral motor/sensory exercises, swallow techniques and positioning.

Speech and language therapists (SLTs) will often provide education and training for those responsible for providing nutrition, hydration and mealtime support (family, professionals, and relevant others) and maintain links with the multi-disciplinary team to ensure good communication. SLTs are pivotal in the team supporting long-term management of those with dysphagia associated with a long-term chronic or progressive condition. There is evidence that some individuals discharged with a percutaneous endoscopic gastrostomy (PEG) tube can have these removed once swallowing improves. The speech and language therapist has a role in monitoring change of swallowing over time. Appropriate insertion or removal of PEGs is associated with improved quality of life and reduced health and social care costs.

Management of dysphagia frequently requires environmental modifications, safe swallowing advice, appropriate dietary modification, and the application of swallowing strategies, which improve the efficiency of swallow function and reduce the risk of aspiration [16–18].

Many of these interventions are designed to minimise symptoms of dysphagia rather than aimed at restoring physiological deficits, and thus are only providing compensatory management. Successful rehabilitation of the pharyngeal phase impairments remains a unique challenge to clinicians. Research into electrical stimulation techniques is gaining interest due to its rehabilitation potential especially for pharyngeal stage swallowing disorders.

Electrical Stimulation in Dysphagia

Electrical stimulation became of interest to clinicians working with people presenting with dysphagia following its successful use as a treatment intervention by physiotherapists for disorders such as foot drop and facial paralysis, where muscles are stimulated to enhance their function and performance [19]. There are, however, a number of different electrico-therapeutic interventions which have been proposed as treatment options for dysphagia and it is necessary to differentiate between them.

We will address the following:

- transcutaneous neuromuscular electrical stimulation (NMES or TNMES), via stimulation to sensory nerve fibres, which primarily supports circulation to the swallowing muscles; or where a muscle contraction is stimulated primarily to strengthen the muscles of swallowing via stimulation to motor nerve fibres
- palatal electrical stimulation, where the palate is stimulated with a specific training device
- pharyngeal electrical stimulation (PES), where an intraluminal catheter is placed in the pharynx as a source of peripheral sensorimotor input
- Functional magnetic stimulation (FMS) a non-invasive method of stimulating the muscles and nerves of swallowing via a coil rather than electrodes
- repetitive transcranial magnetic stimulation (rTMS), a non-invasive method of stimulating the brain, which is thought to be effective in controlling the excitability of the motor cortex
- transdirect current stimulation (tDCS), where a weak electrical current is passed over the brain by the use of surface electrodes
- paired associative stimulation, where pharyngeal electrical stimulation (PES) is paired with direct transcranial electrical stimulation

Each treatment approach will be outlined. The rationale for the use in the treatment of dysphagia will be explained and an overview of the current evidence for each intervention will be reported. The electro-therapies for dysphagia can be divided into two main groups; peripherally delivered and cortically delivered stimulation.

Peripherally Delivered Stimulation Approaches

Transcutaneous Neuromuscular Electrical Stimulation

Transcutaneous neuromuscular electrical stimulation is a relatively new therapeutic intervention for the treatment of swallowing disorders and was first approved by the Food and Drug Administration in USA in 2001 as a treatment for dysphagia. Although it is used as a treatment modality in the USA, it is currently not used in routine clinical practice in the UK and other European countries although the efficacy of NMES for the treatment of dysphagia is being investigated in a small number of research studies.

Transcutaneous neuro-muscular electrical stimulation can be defined as "the external control of innervated but paretic or paralytic muscles by electrical stimulation of the corresponding intact peripheral nerves" [20]. It is referred to in the literature by a potentially confusing variety of acronyms (NMES, TNMES, EMS, TES, TC and the trademarks VitalStim and AMPCARE™). For the consistency for this chapter, the acronym NMES will be used.

Fig. 6.1 Equipment and placement site of the Ampcare™ Effective Swallowing Protocol device (With permission from Professor Patrick McAdoo)

NMES is a non-invasive technique, involving application of an electrical current to the targeted muscle groups via the skin using electrodes placed on the skin surface. The source of the electrical current is usually from a battery powered hand held stimulator unit (see Fig. 6.1).

The hypothesis of transcutaneous electrical stimulation for the treatment of dysphagia is two-fold. Firstly, that by targeting the musculature of the oropharynx with electrical current, the muscles required for swallowing will be strengthened. It is postulated that by increasing the intensity of the electrical current, the electrical field penetrates deeper and depolarizes nerve endings in muscles to produce a muscle contraction. This process aims to strengthen the innervated muscles [21] and may protect striated muscles from atrophy [22, 23]. Secondly, stimulation of the sensory pathways may promote reorganization of the motor cortex and enhance motor relearning.

During volitional muscle contraction that occurs in traditional exercise, type I motor unit fibres are typically recruited first whereas in NMES, the fast twitch muscle fibres (type II motor unit fibres) are activated first and it is postulated that this pattern of recruitment will lead to enhanced muscle strengthening [22, 23]. This is considered to be a positive aspect of NMES in the treatment of dysphagia since a number of the muscles of swallowing are thought to have a higher proportion of type II motor unit fibres; for example the digastric muscle and middle pharyngeal constrictor muscles. However, although muscle strength may be gained during NMES, the carryover to functional activities is not thought to be as great as that of active exercises due to this manner of motor recruitment being opposite to usual recruitment [24]. This is thought to be especially true when the exercise is tailored to match the motor unit activation pattern of the desired movement.

When NMES is combined with traditional swallow exercises, the simultaneous recruitment of both types I and II muscle fibres during the combined therapy is thought to generate larger swallowing muscle force and enhance the therapeutic effect above that of NMES or exercise alone in dysphagia treatment. The greatest gains may thus be obtained when NMES is paired with resistance training and/or functional activities [25]. When using NMES as an adjunct treatment technique, an individual often produces more numerous and more frequent swallows during the treatment session than with exercise alone and this repetitive action of swallowing may help to explain the improved overall therapeutic effect which has been found in some studies [26–29]. Additionally, the electrical stimulation combined with swallowing practise and exercise can increase swallowing excitability in the motor cortex of the brain and facilitate motor learning.

The placement of electrodes during electrical stimulation for treating dysphagia is an area of some controversy particularly as the muscles involved in swallowing are small and many are overlapping. Suprahyoid muscles including the anterior belly of the digastric, the mylohyoid, and the geniohyoid muscles are responsible for the anterior and superior movement of the hyoid. Whilst the infrahyoid muscles such as the sternohyoid, omohyoid, and sternothyroid muscles depress the hyoid.

When swallowing, the movement of the larynx in both an upward and forward direction is critical for closure of the laryngeal vestibule and the reduction in the risk of aspiration occurring during the swallow process. Reduced elevation and superior motion of the larynx, which are common occurrences in people presenting with dysphagia, is usually as a result of reduced hyoid movement.

When the electrodes are placed on the group of infrahyoid muscles, the electrical current is thought to reach the sternohyoid and omohyoid muscles first, because the sternohyoid muscle is larger and closer to the surface than the thyrohyoid muscle. However, as the sternohyoid and omohyoid muscles pull the hyoid bone downwards, this site of electrode placement has been found to result in a downward movement of the hyoid [30, 31]. It is suggested that this could be a detrimental movement to patients who present with dysphagia? as it may put them at greater risk of aspiration as a result of the airway remaining open during the swallowing process [30]. This is especially likely if the individual is consuming diet and/or fluid at the same time as the stimulation is being received.

However, a further theory explored in the literature [30] is that such a movement during swallowing, may produce a resistance against upward displacement of the hyolaryngeal structures and so may strengthen the suprahyoid muscles and thyrohyoid muscle which lift the larynx. With this debate in mind some may thus consider that the electrode placement on the suprahyoid muscles may be a safer placement to achieve hyolaryngeal elevation in dysphagic patients with weak muscles and reduced hyolaryngeal elevation.

One of the most commonly used NMES techniques in the USA for treating patients with dysphagia incorporates electrode placements which stimulate both the suprahyoid and infrahyoid muscles [22]. This technique was developed by a team based in Chattanooga, USA and is marketed under the trade name of VitalStim Therapy. The intervention uses a pair of electrodes usually positioned bilaterally on the digastric muscles and the other on the thyrohyoid muscle. The electrical current is delivered via a hand held stimulator unit for a period of up to 60 min whilst the patient produces voluntary swallows. At regular intervals throughout each treatment session, patients are asked whether they can tolerate greater current intensity. Use of increased intensities facilitates progressively stronger muscle contractions, with the aim of achieving maximum treatment outcomes.

Studies reported in the literature have used the protocol over an intervention period of up to 5 days a week, for up to approximately 4 weeks of intervention. Some authors use this electrode placement with a current intensity at a sensory level only whilst others set the intensity at both a sensory and motor level. Different nerves are thought to be stimulated by increasing the intensity of the electrical stimulation. At the lower levels, the electrical current will stimulate just the afferent nerves (sensory nerves). The patient is reported to feel the electrical stimulation perhaps as a 'tingling sensation' but no muscles are contracting. As the intensity increases, some of the efferent nerves (motor nerves) will be stimulated resulting in a muscle contraction. During the treatment sessions, patients are generally encouraged to swallow boluses of oral intake via voluntary swallowing activity.

In contrast, a further protocol cleared by the FDA in USA for the treatment of dysphagia uses electrodes positioned only on the submental musculature, in order to target the anterior digastric, mylohyoid and geniohyoid muscles (the suprahyoid muscles) as these protract and elevate the hyoid bone and raise the larynx. This protocol is marketed under the trade name of the Ampcare Effective Swallowing Protocol.™

This protocol uses different electrode placement and different treatment parameters to the previously described protocol (Fig. 6.1). However, the electrical current is also provided via a hand held stimulator unit. The stimulus is set according to the maximum patient tolerance level and aims to produce a motor unit response level muscle contraction. This protocol differs from the previously described technique, as the patient is encouraged to carryout simultaneous laryngeal exercises during the stimulation period rather than taking oral intake. The exercises are produced against resistance, by incorporating a specially designed neck brace, which acts as a resistive device for the patient to work against. Pulse duration/width is an adjustable parameter during this technique, allowing the clinician to select the most comfortable parameter for the patient. Treatments are generally 5 days a week for a period of around 4–6 weeks.

The parameters are adjusted during the intervention period to encourage the individual to work harder during the sessions. In Week 1, treatment involves a total of 60 stimulations (each lasting 5 s) during which the patients carry out exercises and then swallow. In Week 2, the rest period between pulses of stimulation is reduced, so that patients receive a total of 72 stimulations during the session. In Weeks 3 and 4, patients receive a total of 90 stimulations.This procedure is postulated to encourage progressive muscle strengthening. The exercises completed during each pulse of stimulation are specifically selected to target hyoid and laryngeal elevation.

The aim of combining the resistive exercises simultaneously with the stimulation aims to strengthen and improve functional swallowing movement patterns through muscle contraction against resistance. It also aims to improve cortical reorganization and neurovascular coupling, and provide an overload principle to muscles, to increase range of motion and strength.

Since an initial study by Freed et al. [22], there have been a considerable number of studies investigating the therapeutic effect of NMES on swallow function. The majority of these have focussed on dysphagia post stroke. Baijens and colleagues [32] have looked at Parkinson's disease and found no significant effects when compared to traditional therapy – however they only used a single session of stimulation. Ryu et al. [33] looked at dysphagia following head and neck cancer and found no significant differences between NMES and traditional therapy.

Within the stroke dysphagia population, there have been conflicting findings within the literature. This may in part be due to the heterogeneity of the treatment protocol across studies – some have used NMES alone versus traditional therapy techniques, whereas others have used it as an adjunct. Differing electrode types have been used, with different electrode application sites and different treatment parameters. Many studies have also been criticised for use of small sample sizes, lack of randomised controls and lack of blinding or inter-rater reliability controls [22, 28, 34].

These limitations make meta-analysis a challenge and so there remains a need for large scale, randomised controlled trials using explicit reporting of electrode type, placement and treatment parameters before decisions regarding clinical adoption of this technique can be made. Several systematic reviews [35, 21] and meta-analysis studies [36–38] have been completed, although they each acknowledge the limitations inherent in combining studies with significant heterogeneity. A Cochrane review in 2012 [39] summarises the position, stating that the evidence on NMES (as with the other electrical stimulation approaches) "remains unclear".

Given the cautionary notes above regarding the difficulty in extrapolating definitive answers from the current evidence base regarding NMES and treatment efficacy post stroke dysphagia, Table 6.1 summarises the main points from the available literature to date.

Palatal Electrical Stimulation

Electrical stimulation via a palatal prosthesis as a treatment for post stroke dysphagia has been explored in a small number of patients who present with delayed triggering of the swallow. This technique involves fitting each patient with an individually made palatal appliance (constructed from a dental impression). Electrodes extend posteriorly from an acrylic plate and are designed to contact the soft palate. The electrodes are not placed at a specific point on the soft palate; rather the aim is to deliver general stimulation to the palate.

Palatal electrical stimulation is founded upon the hypothesis that the stimulation will excite sensory feedback and so result in stimulation of an involuntary swallow reflex. Electrical stimulation is generally provided at 1-s intervals and the patients are asked to swallow a bolus during stimulation [40].

This technique has been explored in a very small number of studies [40, 41] which developed from earlier work on mechanical/thermal stimulation of the faucial arches in order to trigger swallowing. Following a failure to demonstrate treatment efficacy of mechanical/thermal stimulation, these studies investigated whether electrical stimulation to the palate might prove more effective. The earlier study by Park [40] concluded that palatal electrical stimulation had improved swallow function in 2 out of 4 patients in a case series; however the Power study [41] used a real versus sham design on 16 patients with post stroke dysphagia and found no evidence of functional change. The technique has received little attention since this period and is unlikely to be adopted into routine clinical practice, as other electro-therapeutic approaches have offered more promising results.

Pharyngeal Electrical Stimulation

The use of pharyngeal electrical stimulation (PES), as a treatment for dysphagia has been explored primarily by Hamdy and colleagues [42–44], mainly via trials on healthy volunteers and then on patients with dysphagia post stroke.

In this approach, the electrical input is provided via an intraluminal pharyngeal catheter, placed into the pharynx via either the nasal or oral cavity. The catheter is connected to an electrical stimulator base unit, which generates a stimulus according to set parameters.

Table 6.1 Summary points of literature regarding Neuro-muscular electrical stimulation (NMES) in the treatment of dysphagia

Summary of current consensus in the literature on NMES		
Statement	Supporting evidence	Qualifying notes
NMES as an adjunct to targeted traditional therapy techniques is more effective in treating post stroke dysphagia then traditional therapy alone	Lim et al. (2009) [26] Park et al. (2012) [27] Kushner et al. (2013) [28] Lee et al. (2014) [29]	Clarity is required on optimal dose intensity, optimal electrode sites, treatment protocols and timing of therapy post stroke
There is insufficient evidence that NMES alone is effective	In favour of NMES: Freed et al. (2001) [22] Permsirivanich et al. (2009) [69] Gallas et al. (2010) [34] Against NMES: Bulow et al. (2008) [70]	It should be noted that the 2001 and 2010 studies have been strongly criticised for having weak study design, whereas the Bulow study was a multi-centre, randomised controlled trial
Summary of gaps in the current evidence		
Evidence required	Supporting evidence	Qualifying notes
Systematic reviews and meta- analyses have not been able to reach definitive agreement regarding the treatment efficacy of NMES	Systematic reviews in favour of NMES: Carnaby-Mann et al. (2007) [36] Huckabee et al. (2007) [20] Langdon et al. (2010) [71] Tan et al. (2013) [37] Chen et al. (2015) [38] Systematic reviews against NMES: Reviews concluding the evidence is insufficient to answer this: Ayala et al. (2008) [35] Clark et al. (2009) [21] Geeganage et al. (2012) [39]	Authors who have felt that they can reach a conclusion acknowledge that their meta analyses are limited by the heterogeneity of treatment approaches used (eg as an adjunct to traditional therapy or used alone), relatively small number of studies for inclusion, plus study design weaknesses
Further research is required to determine optimum treatment parameters (eg stimulation intensity) and electrode placement	Geeganage et al. (2012) [39] Poorjavad et al. (2014) [68] National Institute for Health and Care Excellence (NICE) (2014) [72]	Clarity is required regarding whether sensory or motor stimulation levels are more effective, also to determine which muscle groups should be targeted for which dysphagic symptoms, and to define electrode placement accordingly
Further research is required to determine the patient groups for which NMES might be effective (eg Stroke, degenerative neurology, cancer)	NICE (2014) [72]	Much of the published studies have focussed on stroke

The stimulation in this technique is described as a sensorimotor input which primarily activates the afferent nerves. However, when given at higher intensities the stimulation can “evoke small twitches of the pharyngeal musculature” ([45] p8). This approach is designed to exploit neuroplasticity by enhancing the excitability and organisation of the motor cortex in the brain. Stimulation is described in studies as being for around 10 min a day for a period of 1–3 days [46].

Much of the earlier research into PES and dysphagia has focussed on stroke – and specifically on the acute phase of stroke [46]. However, Vasant [47] looked at PES in more chronic post stroke dysphagia; concluding that data collection at 3 months post stroke showed that PES expedited recovery of swallow function in comparison to traditional therapy. A Cochrane review by Geeganage et al. [39] reported that PES “reduced pharyngeal transit time” of the bolus during swallowing and this approach therefore justifies further larger randomised controlled trials, particularly studies which evaluate the economic efficacy of this approach, and its longer term health outcomes.

Functional Magnetic Stimulation

A much more recently investigated type of neurorehabilitation of swallowing is functional magnetic stimulation (FMS). This type of neuromodulation involves a current pulse passing through a coil to generate a magnetic field (Fig. 6.2), causing stimulation to nerves and muscles, in FMS the current is applied peripherally, over targeted muscle groups.

FMS stimulates nerves and muscles by changing the electrical potential of the nerve cell wall and if this change is large enough, an action potential in the nerve will be generated. If the nerve is a motor nerve a muscle fibre is activated.

The principles behind FMS can be thought of as largely similar to those for neuromuscular electrical stimulation, but FMS is postulated by some to achieve a greater range of depth to stimulate deep tissue without pain [48].

With FMS it is speculated that it may be possible to induce improved contractibility of pharyngeal muscle groups and neuro-modulation of swallowing-related muscle groups by stimulation of the pharyngeal muscles and their dominant nerves through FMS [49]. One of the afferent pathways of the swallowing reflex is the sensory branch of the vagus nerve from the pharyngeal mucosa. It is speculated that if the vagus nerve is stimulated, it is possible that afferent input from the oropharynx could act on the swallowing reflex centre in the medulla oblongata and on the cerebral cortex. As research protocols using FMS have not involved oral intake, it is thought that this intervention can be carried out safely even for patients with severe dysphagia [49].

It should be noted that currently, this technique has only been investigated by a very small group of researchers, through research studies using small numbers of subjects. These studies have often included uncontrolled trial designs and therefore more research – including larger, randomised controlled trials – will be required before this technique could be considered for translation into clinical practice.

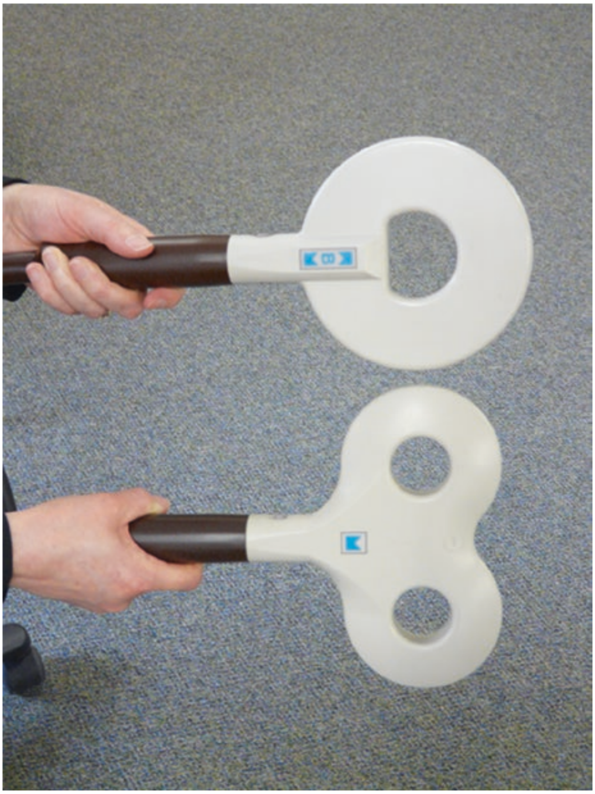

Fig. 6.2 Circular and figure of eight coils for delivery of cortical stimulation (With permission from Professor A.T. Barker)

Cortically Delivered Stimulation Approaches

Repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS) deliver stimulation to the cerebral cortex and have also been investigated as potential tools for facilitating recovery of swallowing function. These two different interventions are considered to be non-invasive and appear to be safe when used according to established safety guidelines [50].

Repetitive Transcranial Magnetic Stimulation

Repetitive transcranial magnetic stimulation (rTMS) is a non-invasive method of stimulating the brain and it is thought to be effective in controlling the excitability of the motor cortex and in reducing the inhibitory imbalance between the hemispheres after stroke [26].

Stimulation is usually via a figure-of-eight coil positioned over one of the two hemispheres of the brain (Figs. 6.2 and 6.3). High frequency magnetic stimulation of an affected hemisphere is postulated to increase the excitability of the cortex,

Fig. 6.3 The first repetitive transcranial magnetic stimulation (rTMS) system developed in Sheffield, UK (With permission from Professor A. Barker)

whereas low-frequency stimulation of the unaffected hemisphere lowers cortical excitability, which might decrease the imbalance between the hemispheres [26, 51, 52]. The stimulation of neuronal networks is thought to outlast the actual stimulation period by 30–60 min [53, 54]. However, the exact recovery mechanism of rTMS is currently unclear. Positive effects of rTMS in stroke patients with dysphagia have been reported in some studies [55–59]. However, each study uses a different magnetic stimulation frequency with no definitely established protocol.

Some of the current evidence regarding rTMS relates to studies on normal subjects, or on virtual lesions [60] a number of small studies have investigated the potential of rTMS to rehabilitate swallow function either by use of rTMS alone [55–58] or in combination with intensive traditional swallow rehabilitation exercises [59]. Each of these studies found positive effects of rTMS on swallow function (although using varying outcome measures). Caution should be applied to these findings however as very small sample sizes have been used to date and several of the studies used uncontrolled designs. Evidence based guidelines for the use of rTMS [61] have included stroke within the clinical applications they evaluated, however their conclusions relate to the effects on general motor deficit, aphasia and hemineglect rather than dysphagia.

Transcranial Direct Current Stimulation

Transcranial direct current stimulation (tDCS) is an additional non-invasive technique that has been investigated in a small number of studies [62–66]. During tDCS a weak electrical current is passed over the brain via two surface electrodes placed on the scalp to produce changes in neuronal excitability [62]. The effects of tDCS are dependent on the direction of the current flow. Doeltgen ([63] p209) suggests that “anodal stimulation of the motor cortex generally produces facilitation of motor cortical excitability, whereas cathodal stimulation reduces it”.

It is postulated that the application of tDCS to the cortical motor and sensory pharyngeal areas can improve swallowing function when combined with traditional swallowing activities [45, 60, 62]. Shigematsu et al. [50] showed beneficial effects of tDCS in conjunction with traditional dysphagia therapy exercises post stroke.

Although tDCS is cheaper and easier to carryout than rTMS, and there have been several studies which have shown favourable results, the sample sizes have been small and there remain unanswered questions regarding the optimum dose for stimulating the motor cortex and also the optimal site for electrode placement over the cerebral cortex.

Many of the studies so far on clinical populations have focussed on stroke. However, Restivo [64] investigated the effects of tDCS versus pharyngeal electrical stimulation (PES) on multiple sclerosis related dysphagia. Patients who received real versus sham tDCS made significantly greater improvement on measures of swallow function and also penetration-aspiration scales under videofluoroscopy, however there was no significant difference between tDCS and PES groups, although the authors reported that tDCS was better tolerated than PES.

Consideration of the timing of the measurement of any beneficial effects must also be made; Yang [65] found no significant difference between tDCS plus traditional therapy versus sham stimulation plus traditional therapy immediately after treatment, however at 3 months, the tDCS group showed improvement on dysphagia outcome measures (when factors of age, time post onset etc. were controlled for). Further research is therefore required to determine whether this intervention should be adopted into clinical practice.

Paired Associative Stimulation (PAS)

Michou and colleagues [66] looked at pairing pharyngeal electrical stimulation with direct transcranial electrical stimulation. They first tested the technique on virtual lesions in healthy volunteers, which they created by repetitive transcranial magnetic stimulation over the pharyngeal cortex. They reported reversing the lesions with

10 min of paired stimulation (compared to sham stimulation) and then went on to evaluate the effects of PAS in a proof-of principle study on six patients with dysphagia post stroke. They found that PAS to the contralesional pharyngeal motor cortex "increased excitability of the unaffected hemisphere," (p 37) accompanied by a reduction in severity of aspiration and/or laryngeal penetration and reduced bolus flow times through the pharynx. This is currently early phase research on a small sample size and the authors acknowledge further research will be required into the potential treatment efficacy of this approach. It is also interesting to speculate whether other stimulation approaches might be paired and to what effect in future studies.

Future Direction

With the application of electrical stimulation techniques to the treatment of dysphagia the aim is to improve or recover swallowing function. The outcome for the patient is likely improved nutritional status and quality of life and the prevention of deleterious health outcomes; moreover the outcome for the health economy is likely reduced costs, due to reduction in occurrence of dysphagia related complications such as aspiration pneumonia and reduction in hospital admissions which are costly to the health economy. Many of the electrical stimulation techniques described in this chapter are showing positive trends as treatment approaches for oropharyngeal dysphagia however before they can be translated into routine clinical practice further research is indicated to answer the emerging questions around dose response effects, standardised protocols for intervention and evidence around which patient populations respond maximally to each method, particularly over the longer term. Many of the studies discussed have included functional changes to the swallow as an outcome measure for example the Functional Oral Intake Scale (FOIS) [67] which describes on a seven point scale the foods and drinks that a person is able to take orally or via a PEG. However fewer studies have included specific physiological measures which could objectively quantify changes in the swallowing biomechanics eg measures of laryngeal elevation or airway closure timings following the e-stimulation intervention.

The positive effects being described in the literature regarding the efficacy of the different electrical stimulation techniques for treating oropharyngeal dysphagia may yield exciting benefits for patients in the coming years. Carefully controlled and fully powered trials are needed to ensure clinical practise is evidence based and targeted at providing maximal clinical benefits to patients.

The selection of a specific modality for an individual patient will need to be based on the underlying physiological features of the swallowing deficit. Knowing the specific features for remediation from detailed assessment procedures will allow specific therapeutic protocols to be developed and specific outcome measures to be utilised. The identification and clear understanding of stimulation effects on the underlying pathophysiology of swallowing disorders and on the central nervous system organisation will allow individualised treatment protocols to be designed [68].

Before we can apply these promising treatments more widely to the general dysphagia population we need to improve our understanding of the efficacy of each individual technique. The challenge for both clinicians and researchers is to complete large scale robust research trials which incorporate control groups, randomisation processes and clear outcome measures on homogeneous samples of patients. Only then can the full potential of electrical stimulation for the treatment of dysphagia be fully determined.

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