Dysphagia after stroke: research advances in treatment interventions

Bendix Labeit, Emilia Michou, Michaela Trapl-Grundschober, Sonja Suntrup-Krueger, Paul Muhle, Philip M Bath, Rainer Dziewas

Lancet Neurol 2024; 23: 418–28

Department of Neurology, Medical Faculty, Heinrich Heine University Duesseldorf, Duesseldorf, North Rhine-Westphalia, Germany (B Labeit MD)**; Department of Speech and Language Therapy, School of Health Rehabilitation Sciences, University of Patras, Patras, Achaia, Greece** (E Michou PhD)**; Centre for Gastrointestinal Sciences, Faculty of Biology, Medicine and Health, University of Manchester and the Manchester Academic Health Sciences Centre (MAHSC), Manchester, Greater Manchester, UK** (E Michou)**; Karl Landsteiner University of Health Sciences, Krems, Lower Austria, Austria** (M Trapl-Grundschober PhDr)**; Division of Neurology, University Hospital Tulln, Tulln, Lower Austria, Austria** (M Trapl-Grundschober)**; Department of Neurology with Institute of Translational Neurology, University Hospital Muenster, Muenster, North Rhine-Westphalia, Germany** (Prof S Suntrup-Krueger MD, P Muhle MD)**; Stroke Trials Unit, Mental Health & Clinical Neuroscience, University of Nottingham, Nottingham, Nottinghamshire, UK** (Prof P M Bath FMedSci)**; Department of Neurology and Neurorehabilitation, Klinikum Osnabrueck – Academic teaching hospital of the University of Muenster, Osnabrueck, Lower Saxony, Germany** (R Dziewas MD)

Correspondence to: Dr Bendix Labeit, Department of Neurology, Medical Faculty and University Hospital Duesseldorf, 40225, Duesseldorf, Germany **Bendix.Labeit@med.uni-duesseldorf.de**

For more on the **International Dysphagia Diet Standardisation Initiative** see https://iddsi.org

After a stroke, most patients have dysphagia, which can lead to aspiration pneumonia, malnutrition, and adverse functional outcomes. Protective interventions aimed at reducing these complications remain the cornerstone of treatment. Dietary adjustments and oral hygiene help mitigate the risk of aspiration pneumonia, and nutritional supplementation, including tube feeding, might be needed to prevent malnutrition. Rehabilitative interventions aim to enhance swallowing function, with different behavioural strategies showing promise in small studies. Investigations have explored the use of pharmaceutical agents such as capsaicin and other Transient-Receptor-Potential-Vanilloid-1 (TRPV-1) sensory receptor agonists, which alter sensory perception in the pharynx. Neurostimulation techniques, such as transcranial direct current stimulation, repetitive transcranial magnetic stimulation, and pharyngeal electrical stimulation, might promote neuroplasticity within the sensorimotor swallowing network. Further advancements in the understanding of central and peripheral sensorimotor mechanisms in patients with dysphagia after a stroke, and during their recovery, will contribute to optimising treatment protocols.

Introduction

Dysphagia refers to the impairment of the transport of food, drink, and saliva from the oral cavity to the gastric entrance. As swallowing requires central control by an extensive cortical, subcortical, and brainstem network, dysphagia commonly occurs in the acute phase of the stroke, with a prevalence of up to 75% of stroke cases.[1] Dysphagia not only compromises quality of life, but can also lead to serious complications. The association with aspiration pneumonia, due to bolus intrusion into the airway, is well established.[2–5] In addition to pneumonia, post-stroke dysphagia contributes to malnutrition by impairing oral intake.[6] As a result of these severe complications, dysphagia is associated with increased in-hospital mortality[7] and additional costs to health-care systems.[8]

Complications of dysphagia often occur early after the stroke, making timely management important.[9] A combination of clinical screening protocols and instrumental gold-standard assessments (such as the flexible endoscopic evaluation of swallowing and the videofluoroscopic swallowing study)[10] have a decisive role in stepwise diagnosis. In a previous Review,[11] we described and discussed diagnostic aspects of post-stroke dysphagia in detail. In this Review, we focus on therapeutic strategies for patients with dysphagia after stroke.

Despite its clinical relevance, dysphagia management has been neglected for many years, possibly because of previously scarce and heterogeneous evidence. This situation has changed markedly, as many studies now provide evidence for the treatment of patients with post-stroke dysphagia. To support evidence-based implementation of treatment, we provide a comprehensive summary of available therapeutic strategies. We begin by proposing a universal minimum standard of care, suitable even for resource-constrained settings. Then, we delve into advanced add-on therapies. Lastly, we outline future research directions in the field.

Dietary interventions

The modification of food and liquid texture is a therapeutic cornerstone in addressing dysphagia, and is based on the principle that aspiration risk varies between different bolus consistencies. Evidence for dietary interventions has been hampered by the use of non-standardised bolus consistencies across studies. Since 2017, the International Dysphagia Diet Standardisation Initiative has provided a framework with standardised definitions and terminology of bolus textures.[12] This framework defines a continuum of eight consistency levels, from low to high viscosity. Levels 0–4 of this framework describe drinks and levels 3–7 describe foods. Levels 3 and 4 represent overlapping consistencies. The framework also includes user-friendly test procedures to determine the respective level of consistency.

Texture modification, such as thickening liquids and pureeing solid foods, is commonly used in dysphagia management. In a study of 120 patients after stroke in Spain,[13] frequency of aspiration decreased steadily with swallowing boluses of increasing viscosity by liquid thickening. In a study of 454 patients after stroke in Japan[14] with individualised dietary interventions incorporating modifications to texture, the frequency of dietary prescription was independently associated with improved nutritional status, better physical function, and shorter hospital stay. A systematic review[15] of studies on texture modification for oropharyngeal dysphagia concluded that thickening of liquid might reduce the frequency of aspiration but, as a negative consequence, texture modification also led to an increase in pharyngeal residue. In a retrospective study of 443 patients with stroke in Japan,[16] the ingestion of foods with low texture levels was associated with malnutrition and sarcopenia. This association might be attributed to decrease in appetite, due to texture-modification[17] and subsequent reduced patient acceptability of this sort of diet.

Because of potential adverse long-term effects, texture modifications are best suited as a short-term early intervention during the acute phase of dysphagia. Thus, training of swallowing function can be started early in dysphagia rehabilitation (eg, even when tube-feeding is still required). Dietary interventions should be implemented as part of an individualised approach based on a case-by-case assessment, preferably with instrumental diagnostic testing. We provide an overview of treatment recommendations derived from international guidelines in panel 1.

Nutritional interventions

The goal of nutritional intervention is to prevent the negative effects of malnutrition. In patients with severe dysphagia who are unable to swallow food, fluids, or medication, tube-feeding becomes necessary to ensure sufficient protein and caloric intake. The FOOD group of studies[20] consisted of three multicentre randomised controlled trials that investigated nutritional interventions for patients after a stroke. In the FOOD-2 trial, which included 859 patients after stroke from 15 countries,[20] there was a statistically non-significant reduction in deaths of 5·8% (p=0·09) in the early tube-feeding group compared with delayed tube-feeding after more than 7 days after admission. In many patients, tube insertion is often needed for drug administration, whether or not feeding is to be commenced immediately. However, tube-feeding does not reduce the rate of aspiration pneumonia,[21,22] as salivary aspiration with oral pathogens still occurs. This risk is also reflected in the high mortality of patients receiving enteral nutrition for a long time.[23] Which caloric regimen is most appropriate in patients with tube-feeding is subject to debate. A randomised controlled trial including 315 patients with severe stroke in China[24] suggested that hypocaloric enteral nutrition is associated with increased mortality, compared with a modified total enteral protocol in which sufficient caloric intake was administered together with prokinetic agents. In two trials (from the UK[25] and Iran[26]), the use of metoclopramide or domperidone as prokinetic drugs reduced the incidence of pneumonia in patients after stroke,[25,26] although this positive effect of metoclopramide was not confirmed in the large European PRECIOUS trial (European Stroke Organisation Conference, May 2023). In a retrospective observational study of critically ill patients after stroke in China,[27] protein intake, but not caloric intake, was associated with reduced mortality at 30 days and at 6 months, suggesting that adequate protein intake might be particularly relevant.[27] The question of whether and when exactly enteral nutrition should be provided via a nasogastric tube or via percutaneous endoscopic gastrostomy (PEG) cannot be conclusively answered on the basis of the available studies. In the FOOD-3 trial, done in 321 participants from 11 countries,[20] the absolute risk of death and poor functional outcome was 7·8% higher in patients who received an early PEG than in patients with a nasogastric tube (p=0·05). It should be noted that the tube was placed considerably later in the 162 patients who received a PEG than in the 159 patients with nasogastric tubes. By contrast, a Cochrane review[28] concluded that nasogastric and PEG nutrition are not associated with differences in case fatality and dependency; indeed, PEG nutrition was associated with fewer treatment failures, less gastrointestinal bleeding, and higher feed delivery than nasogastric feeding. For pragmatic considerations, it seems reasonable not to do the more invasive PEG insertion immediately after stroke, since oral intake recovers within 30 days in the majority of patients.[29] Accordingly, there is a broad consensus that PEG placement should be done if tube-feeding is expected to be required for more than 28 days during the stable phase after stroke.[19]

Given the detrimental effect of malnutrition after stroke, providing extra energy in the form of oral supplements has been considered as a nutritional intervention. In unselected patients (with regard to the risk of malnutrition) on oral nutrition after stroke, the FOOD-1 trial[30] found no benefit of supplemental oral nutrition therapy on mortality or functional outcomes in 4023 patients with stroke, recruited in 15 countries.[30] However, in some patients, oral nutritional supplementation is assumed to have a beneficial effect. A prospective observational study of 454 patients with stroke in Japan that also investigated texture modification[14] investigated dietary interventions,

Panel 1: International guideline recommendations on treatment of post-stroke dysphagia published since 2017

European Stroke Organisation and European Society for Swallowing Disorders guideline for the diagnosis and treatment of post-stroke dysphagia[18]

- Texture-modified diets are recommended based on an appropriate assessment of swallowing. Behavioural swallowing exercises, acupuncture, oral nutritional supplementation, or enteral feeding in patients with risk of malnutrition together with oral health-care interventions are recommended for dysphagia management. Pharmacological and neurostimulation treatments are recommended within a clinical trial setting.

European Society for Clinical Nutrition and Metabolism guideline on clinical nutrition in neurology[19]

- Oral nutritional supplementation is recommended for patients at risk of malnutrition. The guideline states that data on the effect of texture-modified diets and thickened liquids on outcome parameters are insufficient. It therefore recommends the use of texture modification and fluid thickening only after swallowing assessment and when fluid balance and nutritional intake are monitored. Early enteral tube-feeding is recommended for patients with anticipated prolonged severe dysphagia. In the case of enteral feeding for more than 28 days, percutaneous endoscopic gastrostomy tube insertion is recommended.

including oral energy and protein supplementation, within an individualised approach based on nutritional assessment. This approach was independently associated with an increase in muscle mass, improved physical function, and a shortened hospital stay. A randomised controlled trial in 173 patients with stroke done in China[31] evaluated individualised nutritional support, including an individualised nutrition plan in which caloric requirements were calculated. After the intervention, the body composition of the intervention group showed higher lean mass and phase angle and serologically higher protein, albumin, and haemoglobin concentrations[31] than did the group that did not receive the intervention. Thus, the results suggest that individualised nutritional support, including monitoring of caloric intake, might improve the nutritional status of some patients.

In conclusion, the available data suggest that early tube-feeding with adequate caloric intake should be considered in patients with severe dysphagia. PEG placement should be considered in patients who are assumed to require tube-feeding for more than 4 weeks. Furthermore, caloric intake should be closely monitored and individually managed. Oral supplemental nutrition should only be used in some patients at risk for malnutrition when oral intake is sufficiently safe.

Oral hygiene

Aspiration of saliva contaminated with oral pathogens is considered a crucial mechanism for the development of aspiration pneumonia in patients with acute stroke. In line with this mechanism, a PCR analysis done in a study from New Zealand[32] showed that concentrations of oral bacteria such as *Escherichia coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* increased after stroke and that the combined bacterial level at discharge measured with qPCR was associated with development of pneumonia. Conversely, the aim of oral hygiene interventions is to diminish colonisation with oral pathogens. In a randomised controlled trial of 84 patients in China,[33] pneumonia incidence showed a statistically non-significant reduction from 32% to 14% (p=0·052) with an intensified oral hygiene programme, including swabbing teeth and oral soft tissues with chlorhexidine 3 times daily. In a retrospective observational study involving 2771 patients with acute stroke in Japan,[34] the implementation of systematic dental oral care, compared with a period without such care, was associated with a statistically significant reduction in pneumonia. The odds ratios for pneumonia reduction ranged from 0·24 to 0·49 across different care periods, each characterised by varying levels of enhanced dental care. However, other older trials reported either no statistically significant effects[35,36] or an improvement in oral hygiene without effects on respiratory complications.[37] In a meta-analysis,[18] findings from studies of oral hygiene interventions showed a statistically non-significant reduction of pneumonia (p=0·06) and improved oral health outcomes. Therefore, in patients with dysphagia after stroke, oral hygiene should be optimised as much as possible within the available nursing capacity.

Behavioural therapy

Behavioural exercises and manoeuvres are the most widely used therapeutic approach for patients with dysphagia, with several different procedures available to speech and language therapists. Compensatory procedures are based on changing the position of the body and head during swallowing, and aim to achieve immediate improvement by optimising physiological swallowing and bolus flow. Rehabilitative swallowing exercises aim to achieve a long-term effect through muscle training or optimisation of swallowing mechanics. However, many behavioural procedures are now considered to have both short-term compensatory and long-term altering effects, depending on their administration within an exercise programme.

Some studies have addressed the efficacy of behavioural dysphagia therapies, in the context of an individualised approach. A retrospective study of 2994 patients with stroke in Taiwan[38] that used propensity score matching, found an association between swallowing therapy and a lower incidence of pneumonia and improved long-term survival. In the group of patients who received swallowing therapy, a treatment duration of more than 1 month was associated with decreased pneumonia rate, suggesting an intensity-dependent effect. An older but high-quality randomised controlled trial done in 306 patients with stroke in Australia[39] compared usual dysphagia therapy with standard low-intensity swallowing therapy (swallowing compensation strategies and dietary modifications) and with standard high-intensity swallowing therapy (high-frequency direct swallowing exercises and dietary modifications). There was a statistically significant decrease in chest infections and deaths or institutionalisations in the standard swallowing therapy groups. The high-intensity group also showed a greater proportion of patients who were able to return to a normal diet or recover swallowing function.[39] In a Cochrane meta-analysis,[40] various behavioural interventions were associated with improved swallowing ability and reduced the proportion of patients with dysphagia after stroke.

Several studies have assessed the therapeutic effects of specific manoeuvres or exercise protocols. One of those techniques is the modified chin-tuck manoeuvre. In the original chin-tuck manoeuvre, patients tilt their chin down to their chest. This manoeuvre is intended to improve swallowing mechanics due to the change in posture. This technique has been modified into a protocol for long-term effect exercise against resistance. A meta-analysis of eight randomised controlled trials[41] concluded that chin-tuck against resistance leads to improvements in swallowing-safety (five studies) and oral intake (three studies), compared with control interventions. In a subgroup analysis, the chin-tuck-against-resistance intervention was more effective in improving swallowing safety than the shaker exercise (four studies),[41] which is a head-lifting exercise aimed at increasing laryngeal elevation and upper oesophageal sphincter opening. In a randomised controlled trial of 32 patients with stroke in South Korea,[42] the investigators found an improvement in the penetration-aspiration scale and functional oral intake in the shaker exercise group compared with the conventional dysphagia therapy group. Finally, exercise protocols are in use with the aim of strengthening oral, facial, or breathing muscles. A trial of 19 patients with stroke in Sweden[43] investigated oral neuromuscular training, and revealed positive effects on swallowing rate and lip strength; however, no statistically significant differences were found in the analyses of the Videofluoroscopic Swallowing Study. A trial comparing tongue-to-palate resistance training with conventional therapy in 35 patients with stroke in South Korea[44] reported an improvement of tongue strength and oral and pharyngeal parameters assessed with Videofluoroscopic Swallowing Study. Another trial with 19 patients with stroke in the USA[45] reported an increase in functional oral intake associated with device-facilitated lingual exercises. The effect of resistive jaw opening was investigated in 29 patients with stroke in South Korea in another randomised controlled trial,[46] in which liquid penetrations and aspirations were reduced in the intervention group, but not in the control group, in the pre-post comparison, but there was no statistically significant difference between the groups. Training of inspiratory and expiratory muscles is hypothesised to improve cough reflexes and swallowing function. In a study of 109 patients with stroke in Spain,[47] inspiratory and expiratory muscle training was able to strengthen the respective muscles and reduce respiratory complications. A study of 27 patients in South Korea[48] suggested that expiratory muscle strength training contributes to a reduction in penetrations and aspirations of fluids and an improvement in oral intake. Consistent with this finding, a meta-analysis of 11 randomised controlled trials[49] concluded that respiratory muscle training decreases the risk of respiratory complications and reduces penetrations and aspirations with fluid consistency. Electromyographical or visual biofeedback with instrumental visualisation of swallowing impairment can be used to optimise swallowing mechanics or to increase the myographical amplitude of the swallowing muscles.[50,51] Furthermore, various meta-analyses suggest positive therapeutic effects of acupuncture.[18,52–54] However, despite several, often large studies, the evidence for acupuncture remains of low quality[55] due to a paucity of high-quality methods and heterogeneity, and because the therapeutic mechanism of this procedure is largely unknown.

In summary, there are several protocols available for behavioural dysphagia therapy. Easy-to-implement exercise protocols that have been shown to improve dysphagia after stroke include chin-tuck against resistance, shaker exercises, and expiratory muscle strength training (figure 1). Behavioural therapy should be based on the individual dysphagia pattern and its effectiveness should be evaluated on a case-by-case basis during the course of therapy.

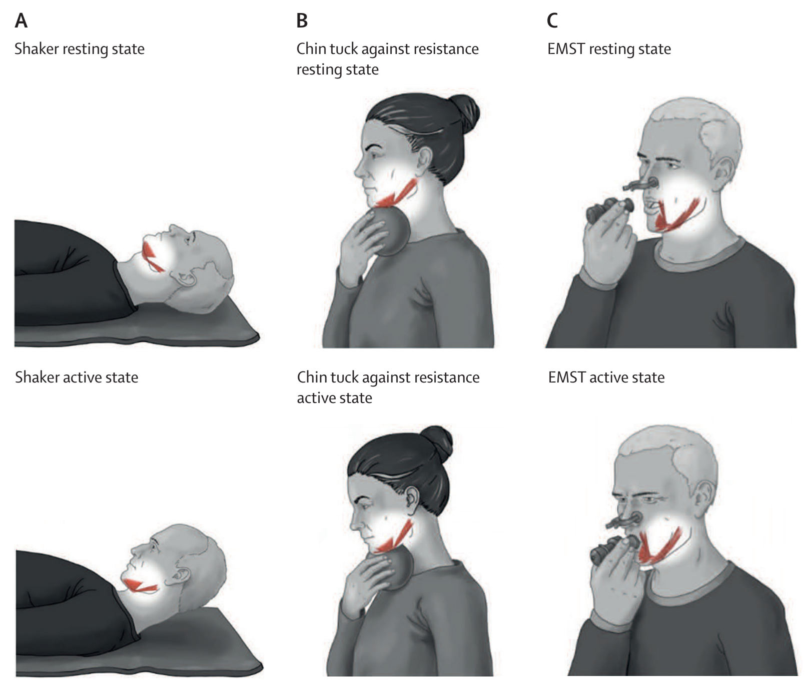

Figure 1: **Behavioural swallowing exercises to treat dysphagia after stroke**
(A) Shaker-exercise, in which the patient lies flat on the floor and holds the head up for 1 min using the supra and infrahyoid muscle groups. This exercise is repeated 3 times for 1 min, following 30 head lifts, 3 times a day for 6 weeks. (B) Chin-tuck against resistance, in which the patient bends the head against a resistance (ie, object placed underneath the chin), involving the suprahyoid and infrahyoid muscle groups. This exercise must be repeated several times per session. (C) Expiratory-Muscle-Strength-Training (EMST), in which the patient blows air against a resistance into a corresponding device, with the participation of pharyngeal muscle groups. This exercise must repeated several times per session.

Pharmacological treatment

Despite promising findings, pharmacological treatment should be used in research settings only, due to a paucity of clear evidence in meta-analyses.[18] Pharmacological treatment consists of medications that have a neuromodulatory effect on swallowing, either at the peripheral sensory level or in the CNS.

A peripherally acting substance used to treat dysphagia is capsaicin, which can be considered a pharmacological sensory stimulus. Capsaicin is an agonist of the TRPV-1 receptor and mediates the release of the neuropeptide substance-P from sensory nerve endings. In nature, capsaicin is found in chili peppers, where it causes the spicy taste. In a randomised controlled trial of 92 patients with stroke in China,[56] capsaicin together with ice was compared with ice stimulation alone. The ice stimulation consisted of using an ice swab to stimulate specific areas,

Panel 2: Neurostimulation procedures

Non-invasive brain stimulation

- Transcranial direct current stimulation (tDCS) and repetitive transcranial magnetic stimulation (rTMS) are non-invasive brain stimulation methods. In tDCS, electrical current is applied over the skull via electrodes, reversibly affecting cortical excitability. The specific effects depend on the polarity of the electrode placement. Anodal stimulation increases cortical excitability and cathodal stimulation decreases it.
- In rTMS, a magnetic field is generated using a coil placed on the scalp. The application of the magnetic field promotes or decreases cortical excitability depending on the stimulation frequency. High-frequency rTMS (eg, >5 Hz) typically enhances cortical activity, while low-frequency rTMS (eg, 1 Hz) reduces it.
- Besides dysphagia rehabilitation, these approaches are also used for modulating brain activity in various neurological and psychiatric conditions.

Methods of peripheral oropharyngeal stimulation

- Pharyngeal electrical stimulation (PES) and neuromuscular electrical stimulation (NMES) involve peripheral stimulation of the pharynx and swallowing muscles.
- In PES, an electric current is applied to the hypopharyngeal mucosa via a catheter providing a sensory stimulus.
- NMES is applied to the cervical region to activate nerves or muscles involved in swallowing function through stimulation of axonal motor or sensory nerve endings and muscle fibres transcutaneously.
- Although the exact mechanisms of peripheral neurostimulation procedures have not been fully elucidated, it is believed that these techniques might exert secondary modulatory effects on the entire swallowing network.

The different stimulation targets and the postulated effects on the swallowing network of the neurostimulation procedures are illustrated in the appendix.

See Online for appendix

including the soft palate, palatine arch, posterior pharyngeal wall, and posterior part of the tongue. This stimulation was administered twice a day, before lunch and dinner. The intervention group showed a greater improvement in dysphagia, as assessed by a water swallowing test and by a clinical swallowing assessment. Furthermore, the intervention group showed higher serum substance-P concentrations after the intervention, compared with the control group.[56] Another randomised controlled trial of 60 patients, also done in China,[57] investigated the effect of capsaicin in addition to tactile thermal stimulation. Tactile thermal stimulation involved applying a 4°C solution to the oropharyngeal mucosa using a cotton swab. In this study, the intervention group showed a greater improvement in swallowing function than the control group, as measured by use of a questionnaire and a clinical assessment with water swallow tests. The results of another randomised controlled trial including 53 patients with haemorrhagic stroke in China[58] suggest that administration of a nebulisation regimen with capsaicin solution can improve cough function and pharyngeal residue. By contrast, in a study in 36 patients with dysphagia after stroke done in Spain[59] in which swallowing was assessed immediately after the application of capsaicin using Videofluoroscopic Swallowing Study, no effect on swallowing physiology was detected, but the investigators reported enhanced excitability in the motor cortex. Besides capsaicin, piperine and menthol also stimulate the TRPV-1 receptor or functionally similar receptors and their use has been associated with improved swallowing function in etiologically heterogeneous patients with dysphagia.[60,61] Other classes of pharmacological agents under investigation, also with inconclusive results, include angiotensin converting enzyme (ACE) inhibitors, which inhibit the degradation of substance-P and sensitise the cough reflex (a known side effect of ACE inhibitors), and dopaminergic agents, which are assumed to shorten the latency of the swallowing response.[18,62]

Neurostimulation

Different peripheral and central neurostimulation procedures have been developed with the aim of inducing neuroplastic changes of the swallowing network. These changes might improve the swallowing function after a stroke (panel 2).

Given the continuous need for further clinical validation and the expectation of new evidence emerging, we recommend prioritisation of the use of these neurostimulation procedures within clinical trial settings.

Transcranial direct current stimulation

The efficacy of transcranial direct current stimulation (tDCS) in stroke swallowing-rehabilitation has been addressed by various meta-analyses, which suggest a positive effect of tDCS on swallowing function.[18,62–73] Partially different results were found in subgroup analyses of the efficacy of different stimulation localisations. In one meta-analysis,[63] positive effects were found for ipsilesional, contralesional, or bilateral anodal (excitatory) stimulation, with a greater effect when the contralesional side was stimulated than with ipsilesional stimulation. In another meta-analysis,[68] only contralesional excitatory stimulation was reported to improve dysphagia. By contrast, another meta-analysis[65] concluded that stimulation of the ipsilesional side showed a more pronounced effect than contralateral stimulation. Yet another meta-analysis[64] found no differences. Individual studies suggest that tDCS also has a positive effect on dysphagia in patients with brainstem stroke.[74,75] and improvement in swallowing function in these patients might be mediated by promoting cortical neuroplasticity.

Repetitive transcranial magnetic stimulation

Various meta-analyses conclude that repetitive transcranial magnetic stimulation (rTMS) can improve swallowing function.[18,40,66–70,76–82] Within subgroup analyses, they also report either no differences in efficacy for specific stimulation locations or the hemisphere in which the stroke was located[76,78,80] or a larger effect size with high-frequency stimulation on the ipsilesional side compared with contralesional stimulation.[68,82] Furthermore, results from randomised controlled trials[83–85] suggest that stimulation of the cerebellum also leads to an improvement in patients with dysphagia and that the therapeutic effect of rTMS might be moderated by the structural integrity of the corticobulbar tract.[86]

Neuromuscular electrical stimulation

Some meta-analyses suggest a therapeutic effect of neuromuscular electrical stimulation on swallowing function.[18,66,70,72,87,88] A study of 31 patients with stroke from South Korea[89] investigated different electrode placement schemes. The results suggest that horizontally placed electrodes on the suprahyoid and infrahyoid muscles achieved the best therapeutic effects compared with vertical placement of the electrodes.[89] In another study of 26 patients from South Korea,[90] there was reduced penetration and aspiration in patients with suprahyoid compared with infrahyoid electrode placement.[90] In a further South Korean trial involving 40 patients, no differences in overall dysphagia severity—assessed via Videofluoroscopic Swallow Study—were observed between the group receiving stimulation of both the masseter and suprahyoid muscles and the group receiving stimulation of the suprahyoid muscle alone.[91]

Pharyngeal electrical stimulation

A meta-analysis of six randomised controlled trials[92] revealed an improvement in swallowing function and an increased proportion of nasal feeding tube removal associated with pharyngeal electrical stimulation. Another meta-analysis comprising five studies[18] narrowly missed the statistical significance threshold for a positive effect of pharyngeal electrical stimulation on swallowing function. Nevertheless, a favourable effect on tracheostomy tube removal was observed in an analysis of tracheotomised patients, using data from two studies.[18] Two additional meta-analyses, each with data from two studies, did not identify therapeutic effects for pharyngeal electrical stimulation (whereas decannulation was not considered).[66,70] Conversely, in a meta-analysis of eight studies evaluating both tracheotomised and non-tracheotomised patients,[68] a statistically significant improvement of dysphagia with pharyngeal electrical stimulation was reported, whereas decannulation success was considered a therapeutic effect. Differentiating between critically ill, tracheotomised patients and less severely affected non-tracheotomised patients could therefore be crucial when assessing the therapeutic effect of pharyngeal electrical stimulation. In line with this finding, a multicentre randomised controlled trial with 69 tracheotomised patients with stroke from various European countries[93] reported a statistically significant higher decannulation rate of 49% in the intervention group, compared with 9% in the control group. In another trial including 60 patients with stroke in Germany[94] who received stimulation within 4 h after extubation, pharyngeal electrical stimulation was associated with improved post-extubation dysphagia, reduced pneumonia incidence, decreased tube-feeding requirements at discharge, and a shorter hospital stay compared with the sham stimulation.

In summary, many randomised controlled trials have investigated neurostimulation procedures, suggesting positive effects on swallowing function. Effects on other important outcome parameters such as aspiration pneumonia, tube-feeding, or mortality are infrequently reported. Furthermore, the question remains as to which of the methods is most suitable for which patient groups. Two meta-analysis comparing the effects of the different neurostimulation methods concluded that rTMS has the greatest effect on swallowing function, ahead of neuromuscular electrical stimulation and tDCS, while no statistically significant effect was shown for pharyngeal electrical stimulation.[66,70] Consistent with this finding, another meta-analysis focussing on tDCS and rTMS showed the best treatment effect for rTMS.[67] A further meta-analysis also showed the largest effect size for rTMS, followed by pharyngeal electrical stimulation and tDCS, while neuromuscular electrical stimulation was not analysed.[68] One potential reason for the variation in the evaluation of pharyngeal electrical stimulation is that, in addition to focusing on swallowing scores, the latter meta-analysis also took decannulation into account as an outcome parameter. In the same meta-analysis, the effect of non-invasive brain stimulation methods was examined depending on the stimulation localisation. The largest effect was seen with bilateral stimulation. For unilateral stimulation, the results differed between tDCS and rTMS, with a larger effect on the ipsilesional side for rTMS and a statistically significant effect for tDCS only on the contralesional side. A trial of 40 patients with stroke in Turkey[95] suggested that the combined use of rTMS and neuromuscular electrical stimulation could result in an additional positive therapeutic response. Reasons for the partly contradictory study results might be the differences in stimulation frequency, localisation of the application, stimulation targets, duration and repetitions of the study protocols, and variations in the study cohorts. Moreover, different and partly contradictory theoretical models for compensatory neuroplasticity as a recovery mechanism of dysphagia exist, leading to different stimulation protocols (figure 2). Due to the partly conflicting data, further studies are needed.

From a pragmatic point of view, and considering the methodological advantages and disadvantages of the various procedures, further conclusions can be drawn about their suitability for certain patients: pharyngeal electrical stimulation is particularly suitable for tracheotomised patients with stroke and with pharyngeal hypoaesthesia and delayed swallowing reflex. TDCS and neuromuscular electrical stimulation can work well as adjunctive treatments with behavioural interventions. By contrast, rTMS, as an adjunct to behavioural interventions, is technically demanding and typically requires transport to a specialised facility. It could

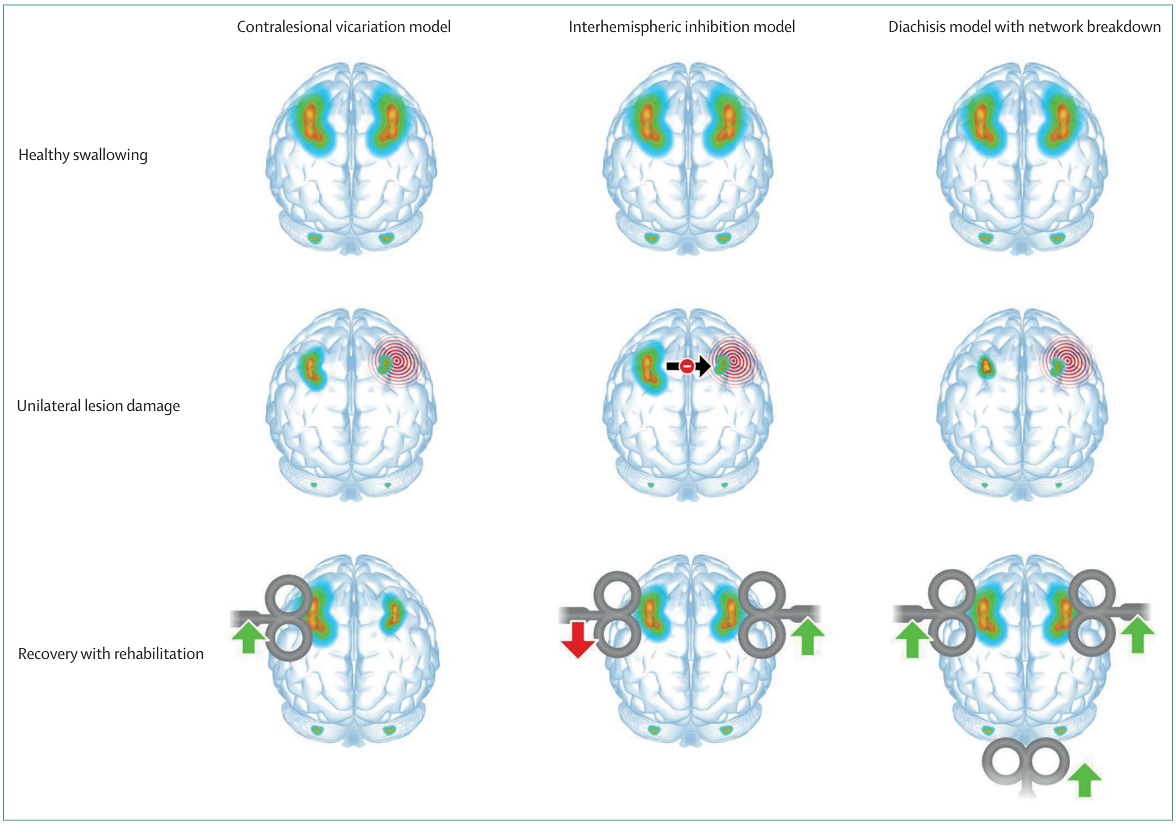

Figure 2: **Hypothetical models of recovery from dysphagia after unilateral stroke and their corresponding non-invasive brain stimulation protocols**
In the healthy brain, swallowing brain activity is represented bilaterally in the sensorimotor cortex and the cerebellum (coloured area with increasing activity from green to yellow). In the contralesional vicariation model, the swallowing network is disrupted after unilateral stroke (red concentric circles). According to the model, recovery of swallowing function is essentially driven by neuroplasticity in the contralateral hemisphere. Therefore, excitatory contralesional stimulation would promote rehabilitation of dysphagia. In the interhemispheric inhibition model, the contralesional hemisphere exerts inhibition over the ipsilesional hemisphere. Therefore, according to this model, inhibitory stimulation in the contralesional hemisphere or excitatory stimulation in the ipsilesional hemisphere could promote recovery of dysphagia. In the diaschisis model, with total network break-down, the stroke lesion causes extensive breakdown of the swallowing network. According to the model, bilateral excitatory stimulation or excitatory stimulation of the cerebellum can support the restoration of the swallowing network in these cases.

therefore be considered for patients with severe but stable conditions.

Conclusions and future directions

Dysphagia is highly prevalent in patients with stroke and can be associated with severe complications. Early management of post-stroke dysphagia is crucial to reduce mortality and improve the patient's quality of life. Various basic therapies are available that should be applied on a large scale (in all settings). Furthermore, there are add-on therapies with increasing evidence of efficacy that should be further explored, particularly within a clinical trial setting.

Therapeutically, the established basic interventions aim primarily at avoiding the complications of dysphagia, without targeting swallowing function itself. Some of these interventions aim to improve oral health and reduce the load of respiratory pathogens in the oral cavity. Dietary interventions to adjust bolus consistencies target swallowing safety, aiming to prevent aspiration, and are used for early swallowing training. Monitoring nutritional status and supplemental or substitutive oral or enteral nourishment can prevent malnutrition. Furthermore, there are several behavioural therapeutic exercise methods with either a compensatory mechanism or aiming to improve swallowing function in the long term. Different stimulation procedures have emerged that aim to trigger and promote neuroplasticity. These procedures include direct brain stimulation methods such as tDCS or rTMS, but also peripheral stimulation interventions such as neuromuscular or pharyngeal electrical stimulation. Several studies have shown promising results, with evidence of improvement in swallowing function for these procedures. However, high-quality studies showing effects on other clinically relevant outcomes such as pneumonia, functional outcome, or mortality are scarce. Besides neurostimulation, pharmacological agents (particularly capsaicin) have shown promising results that suggest improvement of swallowing function or cough facilitated by pharmacological sensory stimulation. Figure 3 presents key management options for dysphagia therapies, tailored according to the timing of admission for stroke.

	Immediate phase (≤2 h)	Acute phase (≤48 h)	Post-acute phase (day 1–30)	Chronic phase (>30 days)
Protective treatment	• Nil by mouth • Oral hygiene	• Dietary interventions • Enteral nutrition: nasogastric tube if necessary • Oral hygiene • Behavioural manoeuvres	• Dietary interventions • Enteral nutrition: nasogastric tube or PEG if necessary • Oral hygiene • Behavioural manoeuvres	• Dietary interventions: texture modifications only cautiously • Enteral nutrition: PEG if necessary • Oral hygiene • Behavioural manoeuvres
Restitutive treatment			• Behavioural exercises • Neurostimulation • Pharmacological interventions	• Behavioural exercises • Neurostimulation • Pharmacological interventions

***Figure 3:* Holistic dysphagia management**
In the acute phase of dysphagia, protective measures with a focus on complication prevention prevail due to the high prevalence of complications in the early course of the disease. Enteral nutrition should be provided with a nasogastric tube, as patients might recover from dysphagia. In the post-acute and chronic stages, all dysphagia therapies should be used, including restitutive measures to improve swallowing function. Enteral nutrition for chronic dysphagia can be provided via PEG. Dietary measures should be used with caution in the chronic phase, due to the risk of adverse effects with long-term use. PEG=percutaneous endoscopic gastrostomy.

The localisation, directionality, and hemispheric coordination of the swallowing network in the context of dysphagia rehabilitation is not yet fully understood. This scarcity of knowledge limits the optimisation of neuromodulation procedures, leading to a variety of stimulation protocols and thus to non-comparable or inconsistent study results.[96] Furthermore, factors such as the paucity of clearly defined responsibilities regarding who can or should perform these interventions, concerns related to recognised risks such as induced epileptic seizures with tDCS and rTMS, regulatory barriers, and paucity of pharmaceutical industry interest have hindered further dissemination. Nevertheless, from a mechanistic perspective, the rehabilitation potential mediated by neuroplasticity is particularly high, given the bilateral central representation of swallowing. A more detailed understanding of central control and neuroplasticity in dysphagia rehabilitation will drive further improvements in neurostimulation. To this end, combined clinical and neuroimaging studies will be crucial.

Furthermore, it is important that evidence-based therapies find their way into clinical practice. In this context, the increasing implementation of instrumental diagnostics allows clinicians to characterise the presentation of a patient with dysphagia, providing insights into the mechanistic patterns of swallowing impairment.[97] Notably, dysphagia observed in patients with a stroke in the medulla oblongata, by contrast with those with supratentorial infarcts, often present with clustered residue in the piriform sinus. This distinctive feature might be attributed to hypercontractility of the upper oesophageal sphincter. For patients with such a specific pathology, targeted interventions aimed at mitigating the hypercontractility of the upper oesophageal sphincter (such as surgical interventions)[98] could yield relevant clinical benefits. In addition to characterising the dysphagia presentation, future advancements will probably lead to a more detailed characterisation of the individual causal factors contributing to dysphagia. This nuanced understanding will have a crucial role in tailoring appropriate therapeutic interventions. Thus, age-related changes in swallowing function can occur in the form of presbyphagia.[99] Accordingly, sarcopenia and reduced swallowing muscle volume have been identified as crucial mechanisms of dysphagia in patients after stroke.[100–103] Specifically, in cases of delayed onset of dysphagia occurring more than 7 days after stroke, sarcopenia could possibly be the leading dysphagia mechanism.[100] For patients with additional sarcopenic cause of dysphagia, whole-body muscle programmes could be effective in dysphagia rehabilitation, as suggested by a retrospective Japanese study in 148 patients that found an association between improved food intake levels and the frequency of chair-stand exercises.[104] Thus, future studies will consider the causes and mechanisms of dysphagia, and help to promote individualised therapies. The outlined progress will enhance dysphagia therapy, leading to a reduction in complications, decreased mortality, and improved quality of life for most patients.

Search strategy and selection criteria

We searched for articles published in English on PubMed between December, 2017 and January, 2024 with the search terms “Dysphagia” AND “Stroke”. We selected articles that reported on therapeutic aspects of dysphagia after stroke. We also considered publications cited in these articles that did not appear in the search algorithm. We included articles published at an earlier date if we considered them still relevant to the field, eg, if the previously selected articles cited a respective article frequently. The final selection of cited articles reflects our subjective assessment of their relevance with respect to the reported results and the methodological quality of the reported work.

Contributors
BL: conceptualisation, literature search, and writing of the manuscript draft. EM: literature search and writing (review and editing). MTG: literature search and writing (review and editing). SSK: writing (review and editing). PM: writing (review and editing). PB: literature search and writing (review and editing). RD: conceptualisation, literature search, and writing (review and editing).

Declaration of interests

BL received a research grant from the medical faculty of the University of Muenster, received financial support from Clexio Bioscience for a study on medication dysphagia in Parkinson's disease, received a research-award from the German Society for Geriatrics/Rolf and Hubertine Schiffbauer Foundation, and received travel support from the German Neurological Society and the United European Gastroenterology. MTG received payment for expert testimony from Phagenesis for involvement in a study as a reviewer of Flexible Endoscopic Evaluation of Swallowing-videos. SSK was supported by an endowed professorship from the Else Kröner Fresenius Stiftung. PMB received support from Phagenesis Ltd (provision of devices for National Institute for Health & Care Research Health Technology Assessment-funded PhEAST trial), and received consulting fees from Phagenesis as member of the advisory board. RD received consulting fees from Daiichi Sankyo and Pfizer; received honoraria for lectures from Daiichi Sankyo, Pfizer, and Alexion; received honoraria from Phagenesis paid to the University Hospital Muenster for participating in the steering committees of different trials; and received reimbursement of travel expenses as a board member of the European Society for Swallowing Disorders and as a board member of the German Dysphagia Society. The other authors declare no competing interests.

References

1 Banda KJ, Chu H, Kang XL, et al. Prevalence of dysphagia and risk of pneumonia and mortality in acute stroke patients: a meta-analysis. *BMC Geriatr* 2022; **22:** 420.

2 Dong Y, Hu B, Huang S, Ye T, Dong Q. The modified volume-viscosity swallow test as a predictor of aspiration pneumonia after acute ischemic stroke. *Clin Neurol Neurosurg* 2021; **200:** 106351.

3 Wu M-R, Chen Y-T, Li Z-X, et al. Dysphagia screening and pneumonia after subarachnoid hemorrhage: findings from the Chinese stroke center alliance. *CNS Neurosci Ther* 2022; **28:** 913–21.

4 Liang J, Yin Z, Li Z, et al. Predictors of dysphagia screening and pneumonia among patients with acute ischaemic stroke in China: findings from the Chinese Stroke Center Alliance (CSCA). *Stroke Vasc Neurol* 2022; **7:** 294–301.

5 Ouyang M, Boaden E, Arima H, et al. Dysphagia screening and risks of pneumonia and adverse outcomes after acute stroke: an international multicenter study. *Int J Stroke* 2020; **15:** 206–15.

6 Scrutinio D, Lanzillo B, Guida P, Passantino A, Spaccavento S, Battista P. Association between malnutrition and outcomes in patients with severe ischemic stroke undergoing rehabilitation. *Arch Phys Med Rehabil* 2020; **101:** 852–60.

7 Huang Z-X, Gu H-Q, Yang X, Wang C-J, Wang Y-J, Li Z-X. Risk factors for in-hospital mortality among acute ischemic stroke patients in China: a nationwide prospective study. *Neurol Res* 2021; **43:** 387–95.

8 Labeit B, Kremer A, Muhle P, et al. Costs of post-stroke dysphagia during acute hospitalization from a health-insurance perspective. *Eur Stroke J* 2022; published online Dec 28. https://doi.org/10.1177/23969873221147740.

9 Bray BD, Smith CJ, Cloud GC, et al. The association between delays in screening for and assessing dysphagia after acute stroke, and the risk of stroke-associated pneumonia. *J Neurol Neurosurg Psychiatry* 2017; **88:** 25–30.

10 Labeit B, Ahring S, Boehmer M, et al. Comparison of simultaneous swallowing endoscopy and videofluoroscopy in neurogenic dysphagia. *J Am Med Dir Assoc* 2021; **23:** 1360–66.

11 Labeit B, Michou E, Hamdy S, et al. The assessment of dysphagia after stroke: state of the art and future directions. *Lancet Neurol* 2023; **22:** 858–70.

12 Cichero JAY, Lam P, Steele CM, et al. Development of international terminology and definitions for texture-modified foods and thickened fluids used in dysphagia management: the IDDSI framework. *Dysphagia* 2017; **32:** 293–314.

13 Bolivar-Prados M, Rofes L, Arreola V, et al. Effect of a gum-based thickener on the safety of swallowing in patients with poststroke oropharyngeal dysphagia. *Neurogastroenterol Motil* 2019; **31:** e13695.

14 Shimazu S, Yoshimura Y, Kudo M, et al. Frequent and personalized nutritional support leads to improved nutritional status, activities of daily living, and dysphagia after stroke. *Nutrition* 2021; **83:** 111091.

15 Steele CM, Alsanei WA, Ayanikalath S, et al. The influence of food texture and liquid consistency modification on swallowing physiology and function: a systematic review. *Dysphagia* 2015; **30:** 2–26.

16 Shimizu A, Fujishima I, Maeda K, et al. Association between food texture levels consumed and the prevalence of malnutrition and sarcopenia in older patients after stroke. *Eur J Clin Nutr* 2022; **76:** 1576–82.

17 Shimizu A, Fujishima I, Maeda K, et al. Texture-modified diets are associated with poor appetite in older adults who are admitted to a post-acute rehabilitation hospital. *J Am Med Dir Assoc* 2021; **22:** 1960–65.

18 Dziewas R, Michou E, Trapl-Grundschober M, et al. European Stroke Organisation and European Society for Swallowing Disorders guideline for the diagnosis and treatment of post-stroke dysphagia. *Eur Stroke J* 2021; **6:** LXXXIX–CXV.

19 Burgos R, Bretón I, Cereda E, et al. ESPEN guideline clinical nutrition in neurology. *Clin Nutr* 2018; **37:** 354–96.

20 Dennis MS, Lewis SC, Warlow C. Effect of timing and method of enteral tube feeding for dysphagic stroke patients (FOOD): a multicentre randomised controlled trial. *Lancet* 2005; **365:** 764–72.

21 Kalra L, Hodsoll J, Irshad S, Smithard D, Manawadu D. Association between nasogastric tubes, pneumonia, and clinical outcomes in acute stroke patients. *Neurology* 2016; **87:** 1352–59.

22 Ho C-H, Lin W-C, Hsu Y-F, Lee I-H, Hung Y-C. One-year risk of pneumonia and mortality in patients with poststroke dysphagia: a nationwide population-based study. *J Stroke Cerebrovasc Dis* 2018; **27:** 1311–17.

23 Sutcliffe L, Flynn D, Price CI. Percutaneous endoscopic gastrostomy and mortality after stroke in England from 2007 to 2018: a retrospective cohort study. *Stroke* 2020; **51:** 3658–63.

24 Zhao J, Yuan F, Song C, et al. Safety and efficacy of three enteral feeding strategies in patients with severe stroke in China (OPENS): a multicentre, prospective, randomised, open-label, blinded-endpoint trial. *Lancet Neurol* 2022; **21:** 319–28.

25 Warusevitane A, Karunatilake D, Sim J, Lally F, Roffe C. Safety and effect of metoclopramide to prevent pneumonia in patients with stroke fed via nasogastric tubes trial. *Stroke* 2015; **46:** 454–60.

26 Allami A, Kianimajd S, Mavandadi S, Paybast S. Evaluation of domperidone efficacy to prevent aspiration pneumonia in patients with acute ischemic stroke: a randomized clinical trial. *Acta Neurol Belg* 2022; **122:** 1337–42.

27 Wang D, Lin Z, Xie L, et al. Impact of early protein provision on the mortality of acute critically ill stroke patients. *Nutr Clin Pract* 2021; **37:** 861–88.

28 Geeganage C, Beavan J, Ellender S, Bath PMW. Interventions for dysphagia and nutritional support in acute and subacute stroke. *Cochrane Database Syst Rev* 2012; **10:** CD000323.

29 Galovic M, Stauber AJ, Leisi N, et al. Development and validation of a prognostic model of swallowing recovery and enteral tube feeding after ischemic stroke. *JAMA Neurol* 2019; **76:** 561–70.

30 Dennis MS, Lewis SC, Warlow C. Routine oral nutritional supplementation for stroke patients in hospital (FOOD): a multicentre randomised controlled trial. *Lancet* 2005; **365:** 755–63.

31 Yan X-L, Liu Z, Sun Y, et al. Individualized nutritional support for hospitalized patients with oropharyngeal dysphagia after stroke: a randomized controlled trial. *Front Nutr* 2022; **9:** 843945.

32 Perry SE, Huckabee M-L, Tompkins G, Milne T. The association between oral bacteria, the cough reflex and pneumonia in patients with acute stroke and suspected dysphagia. *J Oral Rehabil* 2020; **47:** 386–94.

33 Yuan D, Zhang J, Wang X, Chen S, Wang Y. Intensified oral hygiene care in stroke-associated pneumonia: a pilot single-blind randomized controlled trial. *Inquiry* 2020; **57:** 46958020968777.

34 Ozaki K, Tohara H, Baba M, Teranaka S, Kawai Y, Komatsumoto S. A dentist-led oral care system can prevent stroke-associated pneumonia: the effects of early Intervention by dental team. *J Multidiscip Healthc* 2023; **16:** 2937–45.

35 Chipps E, Gatens C, Genter L, et al. Pilot study of an oral care protocol on poststroke survivors. *Rehabil Nurs* 2014; **39:** 294–304.

36 Lam OLT, McMillan AS, Samaranayake LP, Li LSW, McGrath C. Effect of oral hygiene interventions on opportunistic pathogens in patients after stroke. *Am J Infect Control* 2013; **41:** 149–54.
37 Kuo Y-W, Yen M, Fetzer S, Lee J-D, Chiang L-C. Effect of family caregiver oral care training on stroke survivor oral and respiratory health in Taiwan: a randomised controlled trial. *Community Dent Health* 2015; **32:** 137–42.
38 Lo Y-K, Fu T-C, Chen CP, Yuan S-S, Hsu C-C. Involvement of swallowing therapy is associated with improved long-term survival in patients with post-stroke dysphagia. *Eur J Phys Rehabil Med* 2019; **55:** 728–34.
39 Carnaby G, Hankey GJ, Pizzi J. Behavioural intervention for dysphagia in acute stroke: a randomised controlled trial. *Lancet Neurol* 2006; **5:** 31–37.
40 Bath PM, Lee HS, Everton LF. Swallowing therapy for dysphagia in acute and subacute stroke. *Cochrane Database Syst Rev* 2018; **10:** CD000323.
41 Liu J, Wang Q, Tian J, et al. Effects of chin tuck against resistance exercise on post-stroke dysphagia rehabilitation: A systematic review and meta-analysis. *Front Neurol* 2023; **13:** 1109140.
42 Choi J-B, Shim S-H, Yang J-E, Kim H-D, Lee D-H, Park J-S. Effects of Shaker exercise in stroke survivors with oropharyngeal dysphagia. *NeuroRehabilitation* 2017; **41:** 753–57.
43 Hägglund P, Hägg M, Levring Jäghagen E, Larsson B, Wester P. Oral neuromuscular training in patients with dysphagia after stroke: a prospective, randomized, open-label study with blinded evaluators. *BMC Neurol* 2020; **20:** 405.
44 Kim HD, Choi JB, Yoo SJ, Chang MY, Lee SW, Park JS. Tongue-to-palate resistance training improves tongue strength and oropharyngeal swallowing function in subacute stroke survivors with dysphagia. *J Oral Rehabil* 2017; **44:** 59–64.
45 Krekeler BN, Yee J, Kurosu A, et al. Effects of device-facilitated lingual strengthening therapy on dysphagia related outcomes in patients post-stroke: a randomized controlled trial. *Dysphagia* 2023; **38:** 1551–67.
46 Park J-S, An D-H, Kam K-Y, Yoon T, Kim T, Chang M-Y. Effects of resistive jaw opening exercise in stroke patients with dysphagia: a double-blind, randomized controlled study. *J Back Musculoskeletal Rehabil* 2020; **33:** 507–13.
47 Messaggi-Sartor M, Guillen-Solà A, Depolo M, et al. Inspiratory and expiratory muscle training in subacute stroke: a randomized clinical trial. *Neurology* 2015; **85:** 564–72.
48 Park JS, Oh DH, Chang MY, Kim KM. Effects of expiratory muscle strength training on oropharyngeal dysphagia in subacute stroke patients: a randomised controlled trial. *J Oral Rehabil* 2016; **43:** 364–72.
49 Zhang W, Pan H, Zong Y, Wang J, Xie Q. Respiratory muscle training reduces respiratory complications and improves swallowing function after stroke: a systematic review and meta-analysis. *Arch Phys Med Rehabil* 2021; **103:** 1179–91.
50 Archer SK, Smith CH, Newham DJ. Surface electromyographic biofeedback and the effortful swallow exercise for stroke-related dysphagia and in healthy ageing. *Dysphagia* 2021; **36:** 281–92.
51 Vose AK, Marcus A, Humbert I. Kinematic visual biofeedback improves accuracy of swallowing maneuver training and accuracy of clinician cues during training in stroke patients with dysphagia. *PM R* 2019; **11:** 1159–69.
52 Lu Y, Chen Y, Huang D, Li J. Efficacy of acupuncture for dysphagia after stroke: a systematic review and meta-analysis. *Ann Palliat Med* 2021; **10:** 3410–22.
53 Zhong L, Wang J, Li F, Bao X, Liu H, Wang P. The effectiveness of acupuncture for dysphagia after stroke: a systematic review and meta-analysis. *Evid Based Complement Alternat Med* 2021; **2021:** 8837625.
54 Wang P, Ma X, Huang J, et al. Effect of acupuncture treatment on dysphagia caused by pseudobulbar paralysis after stroke: a systematic review and meta-analysis. *Ann Palliat Med* 2022; **11:** 2257–64.
55 Tian Z-Y, Liao X, Gao Y, et al. An overview of systematic reviews and meta-analyses on acupuncture for post-acute stroke dysphagia. *Geriatrics (Basel)* 2019; **4:** 68.
56 Cui F, Yin Q, Wu C, et al. Capsaicin combined with ice stimulation improves swallowing function in patients with dysphagia after stroke: a randomised controlled trial. *J Oral Rehabil* 2020; **47:** 1297–303.
57 Wang Z, Wu L, Fang Q, Shen M, Zhang L, Liu X. Effects of capsaicin on swallowing function in stroke patients with dysphagia: a randomized controlled trial. *J Stroke Cerebrovasc Dis* 2019; **28:** 1744–51.
58 Chao W, You-Qin M, Hong C, et al. Effect of capsaicin atomization on cough and swallowing function in patients with hemorrhagic stroke: a randomized controlled trial. *J Speech Lang Hear Res* 2023; **66:** 503–12.
59 Cabib C, Nascimento W, Rofes L, et al. Short-term neurophysiological effects of sensory pathway neurorehabilitation strategies on chronic poststroke oropharyngeal dysphagia. *Neurogastroenterol Motil* 2020; **32:** e13887.
60 Rofes L, Arreola V, Martin A, Clavé P. Effect of oral piperine on the swallow response of patients with oropharyngeal dysphagia. *J Gastroenterol* 2014; **49:** 1517–23.
61 Ebihara T, Ebihara S, Watando A, et al. Effects of menthol on the triggering of the swallowing reflex in elderly patients with dysphagia. *Br J Clin Pharmacol* 2006; **62:** 369–71.
62 Cheng I, Sasegbon A, Hamdy S. Effects of pharmacological agents for neurogenic oropharyngeal dysphagia: a systematic review and meta-analysis. *Neurogastroenterol Motil* 2022; **34:** e14220.
63 Lin Q, Lin S-F, Ke X-H, Jia X-F, Huang D-B. A systematic review and meta-analysis on the effectiveness of transcranial direct current stimulation on swallowing function of poststroke patients. *Am J Phys Med Rehabil* 2022; **101:** 446–53.
64 Marchina S, Pisegna JM, Massaro JM, et al. Transcranial direct current stimulation for post-stroke dysphagia: a systematic review and meta-analysis of randomized controlled trials. *J Neurol* 2021; **268:** 293–304.
65 Zhao N, Sun W, Xiao Z, et al. Effects of transcranial direct current stimulation on poststroke dysphagia: a systematic review and meta-analysis of randomized controlled trials. *Arch Phys Med Rehabil* 2022; **103:** 1436–47.
66 Chiang C-F, Lin M-T, Hsiao M-Y, Yeh Y-C, Liang Y-C, Wang T-G. Comparative efficacy of noninvasive neurostimulation therapies for acute and subacute poststroke dysphagia: a systematic review and network meta-analysis. *Arch Phys Med Rehabil* 2019; **100:** 739–750.e4.
67 Li L, Huang H, Jia Y, et al. Systematic review and network meta-analysis of noninvasive brain stimulation on dysphagia after stroke. *Neural Plast* 2021; **2021:** 3831472.
68 Cheng I, Sasegbon A, Hamdy S. Effects of neurostimulation on poststroke dysphagia: a synthesis of current evidence from randomized controlled trials. *Neuromodulation* 2021; **24:** 1388–401.
69 Tan SW, Wu A, Cheng LJ, Wong SH, Lau Y, Lau ST. The effectiveness of transcranial stimulation in improving swallowing outcomes in adults with poststroke dysphagia: a systematic review and meta-analysis. *Dysphagia* 2022; **37:** 1796–813.
70 Wang T, Dong L, Cong X, et al. Comparative efficacy of non-invasive neurostimulation therapies for poststroke dysphagia: a systematic review and meta-analysis. *Neurophysiol Clin* 2021; **51:** 493–506.
71 He K, Wu L, Huang Y, et al. Efficacy and safety of transcranial direct current stimulation on post-stroke dysphagia: a systematic review and meta-analysis. *J Clin Med* 2022; **11:** 2297.
72 Banda KJ, Wu K-C, Jen H-J, et al. Comparative effectiveness of combined and single neurostimulation and traditional dysphagia therapies for post-stroke dysphagia: a network meta-analysis. *Neurorehabil Neural Repair* 2023; **37:** 194–204.
73 Gómez-García N, Álvarez-Barrio L, Leirós-Rodríguez R, Soto-Rodríguez A, Andrade-Gómez E, Hernández-Lucas P. Transcranial direct current stimulation for post-stroke dysphagia: a meta-analysis. *J Neuroeng Rehabil* 2023; **20:** 165.
74 Mao H, Lyu Y, Li Y, et al. Clinical study on swallowing function of brainstem stroke by tDCS. *Neurol Sci* 2022; **43:** 477–84.
75 Wang Z-Y, Chen J-M, Lin Z-K, Ni G-X. Transcranial direct current stimulation improves the swallowing function in patients with cricopharyngeal muscle dysfunction following a brainstem stroke. *Neurol Sci* 2020; **41:** 569–74.
76 Li H, Li L, Zhang R, et al. Effectiveness of repetitive transcranial magnetic stimulation on poststroke dysphagia: a meta-analysis of randomized-controlled trials. *Int J Rehabil Res* 2022; **45:** 109–17.
77 Yang W, Cao X, Zhang X, Wang X, Li X, Huai Y. The effect of repetitive transcranial magnetic stimulation on dysphagia after stroke: a systematic review and meta-analysis. *Front Neurosci* 2021; **15:** 769848.

78 Wen X, Liu Z, Zhong L, et al. The effectiveness of repetitive transcranial magnetic stimulation for post-stroke dysphagia: a systematic review and meta-analysis. *Front Hum Neurosci* 2022; **16:** 841781.

79 Hsiao M-Y, Choo YJ, Liu I-C, Boudier-Revéret M, Chang MC. Effect of repetitive transcranial magnetic stimulation on post-stroke dysphagia: a meta-analysis of stimulation frequency, stimulation site, and timing of outcome measurement. *Dysphagia* 2023; **38:** 435–45.

80 Qiao J, Ye Q-P, Wu Z-M, Dai Y, Dou Z-L. The effect and optimal parameters of repetitive transcranial magnetic stimulation on poststroke dysphagia: a meta-analysis of randomized controlled trials. *Front Neurosci* 2022; **16:** 845737.

81 Xie Y-L, Wang S, Jia J-M, et al. Transcranial magnetic stimulation for improving dysphagia after stroke: a meta-analysis of randomized controlled trials. *Front Neurosci* 2022; **16:** 854219.

82 Sun M, Chen K, He Y, Zhang Y, Zhuo Y, Zhuang H. Effect of repetition of rTMS at different frequencies on the efficacy of swallowing disorders after stroke: a systematic review and meta-analysis. *Medicine (Baltimore)* 2023; **102:** e35504.

83 Zhong L, Rao J, Wang J, et al. Repetitive transcranial magnetic stimulation at different sites for dysphagia after stroke: a randomized, observer-blind clinical trial. *Front Neurol* 2021; **12:** 625683.

84 Zhong L, Wen X, Liu Z, et al. Effects of bilateral cerebellar repetitive transcranial magnetic stimulation in poststroke dysphagia: a randomized sham-controlled trial. *NeuroRehabilitation* 2023; **52:** 227–34.

85 Dai M, Qiao J, Shi Z, et al. Effect of cerebellar transcranial magnetic stimulation with double-cone coil on dysphagia after subacute infratentorial stroke: a randomized, single-blinded, controlled trial. *Brain Stimul* 2023; **16:** 1012–20.

86 Wang L, Wang F, Lin Y, et al. Treatment of post-stroke dysphagia with repetitive transcranial magnetic stimulation based on the bimodal balance recovery model: a pilot study. *J Integr Neurosci* 2023; **22:** 53.

87 Wang Y, Xu L, Wang L, Jiang M, Zhao L. Effects of transcutaneous neuromuscular electrical stimulation on post-stroke dysphagia: a systematic review and meta-analysis. *Front Neurol* 2023; **14:** 1163045.

88 Wang Z, Xiao Z, Shen Q, Zhao N, Zhang W. Neuromuscular electrical stimulation for post-stroke dysphagia treatment: a systemic evaluation and meta-analysis of randomized controlled trials. *Dysphagia* 2023; published online Nov 1. https://doi.org/10.1007/s00455-023-10626-6

89 Huh J-W, Park E, Min Y-S, et al. Optimal placement of electrodes for treatment of post-stroke dysphagia by neuromuscular electrical stimulation combined with effortful swallowing. *Singapore Med J* 2020; **61:** 487–91.

90 Oh D-H, Park J-S, Kim H-J, Chang M-Y, Hwang N-K. The effect of neuromuscular electrical stimulation with different electrode positions on swallowing in stroke patients with oropharyngeal dysphagia: a randomized trial. *J Back Musculoskeletal Rehabil* 2020; **33:** 637–44.

91 Lee KW, Kim SB, Lee JH, Lee SJ, Park JG, Jang KW. Effects of Neuromuscular Electrical Stimulation for Masseter Muscle on Oral Dysfunction After Stroke. *Ann Rehabil Med* 2019; **43:** 11–18.

92 Liu Z, Cheng J, Tan C, Liu H, Han D. Pharyngeal cavity electrical stimulation-assisted swallowing for post-stroke dysphagia: a systematic review and meta-analysis of randomized controlled studies. *Dysphagia* 2023; published online Dec 23. https://doi.org/10.1007/s00455-023-10644-4

93 Dziewas R, Stellato R, van der Tweel I, et al. Pharyngeal electrical stimulation for early decannulation in tracheotomised patients with neurogenic dysphagia after stroke (PHAST-TRAC): a prospective, single-blinded, randomised trial. *Lancet Neurol* 2018; **17:** 849–59.

94 Suntrup-Krueger S, Labeit B, Marian T, et al. Pharyngeal electrical stimulation for postextubation dysphagia in acute stroke: a randomized controlled pilot trial. *Crit Care* 2023; **27:** 383.

95 Bengisu S, Demir N, Krespi Y. Effectiveness of conventional dysphagia therapy (CDT), neuromuscular electrical stimulation (NMES), and transcranial direct current stimulation (tDCS) in acute post-stroke dysphagia: a comparative evaluation. *Dysphagia* 2023; **39:** 77–91.

96 Cheng I, Hamdy S. Current perspectives on the benefits, risks, and limitations of noninvasive brain stimulation (NIBS) for post-stroke dysphagia. *Expert Rev Neurother* 2021; **21:** 1135–46.

97 Warnecke T, Labeit B, Schroeder J, et al. Neurogenic dysphagia: systematic review and proposal of a classification system. *Neurology* 2021; **96:** e876–89.

98 Shibata S, Kagaya H, Ozeki Y, et al. Effect of laryngeal suspension and upper esophageal sphincter myotomy for severe dysphagia due to brainstem disease. *Ann Otol Rhinol Laryngol* 2020; **129:** 689–94.

99 Labeit B, Muhle P, von Itter J, et al. Clinical determinants and neural correlates of presbyphagia in community-dwelling older adults. *Front Aging Neurosci* 2022; **14:** 912691.

100 Shimizu A, Fujishima I, Maeda K, et al. Delayed dysphagia may be sarcopenic dysphagia in patients after stroke. *J Am Med Dir Assoc* 2021; **22:** 2527–33.e1.

101 Sakai K, Katayama M, Nakajima J, et al. Temporal muscle thickness is associated with the severity of dysphagia in patients with acute stroke. *Arch Gerontol Geriatr* 2021; **96:** 104439.

102 Yang S-M, Wu H-W, Lin Y-H, Lai T-J, Lin M-T. Temporalis and masseter muscle thickness as predictors of post-stroke dysphagia after endovascular thrombectomy. *Eur J Radiol* 2023; **165:** 110939.

103 Fukuma K, Kamada M, Yamamoto K, et al. Pre-existing sarcopenia and swallowing outcomes in acute stroke patients. *Clin Nutr* 2023; **42:** 1454–61.

104 Yoshimura Y, Wakabayashi H, Nagano F, Bise T, Shimazu S, Shiraishi A. Chair-stand exercise improves post-stroke dysphagia. *Geriatr Gerontol Int* 2020; **20:** 885–91.