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Scoping review to identify and map non-pharmacological, non-surgical treatments for dysphagia following moderate-to-severe acquired brain injury

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ABSTRACT

Introduction Dysphagia is a common and critical consequence of acquired brain injury (ABI) and can cause severe complications. Dysphagia rehabilitation is transforming from mainly compensatory strategies to the retraining of swallowing function using principles from neuroscience. However, there are no studies that map interventions available to retrain swallowing function in patients with moderate-to-severe ABI.

Objective To systematically map the accessible research literature to answer the research question: *Which non-surgical, non-pharmacological interventions are used in the treatment of dysphagia in patients with moderate and severe ABI in the acute and subacute phase?*

Design Scoping review based on the methodology of Arksey and O'Malley and methodological advancement by Levac *et al*.

Data sources MEDLINE, Embase, Cochrane Library, CINAHL, PsycINFO, Web of Science, OTseeker, speechBITE and PEDro were searched up until 14 March 2021.

Eligibility criteria All studies reporting rehabilitative interventions within 6 months of injury for patients with moderate-to-severe ABI and dysphagia were included.

Data extraction and synthesis Data was extracted by two independent reviewers and studies were categorised based on treatment modality.

Results A total of 21 396 records were retrieved, and a final of 26 studies were included. Interventions were categorised into *cortical* or *non-cortical* stimulation of the swallowing network. Cortical stimulation interventions were repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation. Non-cortical were complex swallowing interventions, neuromuscular electrical stimulation, pharyngeal electrical stimulation (PES), sensory stimulation, strengthening exercises and respiratory muscle training.

Conclusion This scoping review provides an overview of rehabilitative dysphagia interventions for patients with moderate and severe ABI, predominantly due to stroke, in the acute and subacute phase. Positive tendencies towards beneficial effects were found for rTMS, complex swallowing interventions, PES and cervical strengthening. Future studies could benefit from clear reporting of patient diagnosis and disease severity, the use of more standardised treatment protocols or algorithms and fewer but standardised outcome measures to enable comparison of effects across studies and interventions.

Strengths and limitations of this study

- An extensive search in multiple databases and subsequent consultation with key informants led to an exhaustive mapping of rehabilitation approaches in neurogenic dysphagia.
- Data extraction variables thoroughly described the study sample, intervention, control, timing and dose, outcome measures and results reported.
- A categorisation for included interventions is used to map dysphagia rehabilitation based on stimulation site of the swallowing network.
- There was no quality assessment of the included studies; however, a summary of reported results from studies divided in subcategories is presented.

INTRODUCTION

Dysphagia (swallowing disorder) is a common and critical consequence of acquired brain injury (ABI).[1–5] Dysphagia can impact the general health and the consequences of swallowing disability are severe, causing either impaired efficiency, safety of the swallow or both. Impaired efficiency can lead to dehydration, malnutrition and weight loss, while impaired safety can cause laryngeal penetration of saliva, food or liquid or tracheobronchial aspiration that may cause pneumonia, or lead to choking and death.[1 4 6 7] The incidence of dysphagia is reported as high as 93% following severe brain injury.[8] Dysphagia can prolong hospital length of stay and is associated with significantly higher healthcare costs of up to 40%, regardless of whether the patient develops pneumonia.[9 10]

Dysphagia is recognised by the WHO as a medical disability, having profound psychological and social consequences for the individual,

impacting negatively on quality of life.[11 12] Difficulty swallowing can cause frustration, anxiety and embarrassment during mealtimes, especially at social events where eating should be pleasurable and may result in the individual becoming less active and participating less in society.[12 13]

The clinical presentation of swallowing impairment is dependent on the origin and type of ABI, and may be caused by sensory and/or motor deficits.[14] Swallowing is a multifaceted process requiring interaction and coordination of conscious and autonomous responses with precise coordination of multiple muscle groups in the oral cavity, pharynx and larynx.[15] Swallowing is coordinated mainly by a swallowing centre, an interneuronal network centred in the brain stem, receiving peripheral sensory inputs from the pharynx and larynx and central inputs from the cortex.[16] Any damage to the neurophysiological pathway can result in dysphagia, caused by a loss of functional connectivity within the neural swallowing network.

Patients with severe brain injuries are not always able to actively participate in exercises or change of behaviour for safe swallowing techniques in rehabilitation of swallowing and eating function, due to sensorimotor, perceptive, cognitive dysfunctions or impaired consciousness. Thus, following instructions for exercises, behavioural adjustments and self-training is not an option and limits the choice of intervention.

Scientists and clinicians have long been occupied and concerned about how to treat dysphagia and to transfer knowledge about neuroplasticity and motor learning from movement science and neuroscience into the recovery of swallowing function.[17] Several reviews have addressed dysphagia rehabilitation using specific approaches or within limited diagnosis groups of ABI,[18–21] but none have offered a more comprehensive overview. For further details, please see the published protocol.[22] Many unanswered questions remain when it comes to choosing the adequate treatment approach, dose and intensity for different populations suffering from dysphagia. There is no clear evidence or consensus about when to compensate or retrain swallowing function or assessment of whether an intervention is applicable in the clinical setting.[17 23 24] However, the paradigm for dysphagia treatment is changing from compensatory strategies, such as modified consistencies for food and liquid and postural changes, to the recovery and re-training of swallowing function relying on neuroscientific results.[10 23 24]

Research, especially in patients with severe brain injury is sparse.[25] Still, the consequences of dysphagia might be devastating for the patient's quality of life, level of activity and participation and lead to a massive burden for caregivers and the healthcare systems. Thus, the long-term goal of dysphagia rehabilitation is to re-establish safe swallowing and eating function and protection of airways for maximal activity and participation in daily life.

REVIEW OBJECTIVE

The objective of this scoping review is to systematically map the accessible research literature to answer the research question: *Which non-surgical, non-pharmacological interventions are used in the treatment of dysphagia in patients with moderate and severe ABI in the acute and subacute phase?*

METHODS

The study is designed and conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) reporting guidelines.[26] The protocol for this scoping review has been published earlier.[22]

A scoping review approach based on the methodology by Arksey and O'Malley and methodological advancement by Levac *et al* was applied.[27 28] This method allows for an elaborate search of the literature and the broad scope of the research subject. The method entails six stages of the scoping review process: (1) identifying the research question; (2) identifying relevant studies; (3) selecting studies; (4) charting the data; (5) collating, summarising and reporting the results and (6) consulting with relevant stakeholders.[28] Stage 1 is described in detail in the published protocol.[22]

Stages 2 and 3: identifying and selecting relevant studies

Database selection and search strategy

We searched the following electronic bibliographic databases: MEDLINE (Ovid); Cochrane Central Register of Controlled Trials (CENTRAL, The Cochrane Library); Embase (Ovid); CINAHL (EBSCO); PsycINFO; Science Citation Index Expanded on Web of Science; OTseeker; speechBITE; and PEDro.

The search strategy included terms related to the condition and population. Specific keywords identified in the preliminary search were introduced in the final search strategy. The search strategy for MEDLINE (the preliminary) was adapted for searches in all other databases (online supplemental appendix 1).

References of relevant adjacent reviews and included papers were screened for further relevant studies.

Furthermore, we searched for ongoing and unidentified clinical trials on:

Google Scholar; Database on Research in Stroke (DORIS); The Turning Research into Practice (TRIP) Database; ClinicalTrials.gov; EU Clinical Trial Register; Chinese Clinical Trial Registry (ChCTR); International Standard Randomised Controlled Trial Number (ISRCTN) registry; Pan African Clinical Trials Registry (PACTR); Australian New Zealand Clinical Trials Registry (ANZCTR); Clinical Trials Registry—India (CTRI); and the WHO International Clinical Trials Registry Platform (ICTRP) search portal.

Asian language studies were excluded as acceptable translation was not possible. There was no restriction on publication date.

The electronic search was based on patient characteristics and did not include search terms for any treatment or intervention, thus reducing the risk of excluding relevant studies. The final search was conducted on 14 March 2021, by two authors (SJE and DJC). All five authors were included in the development of the search strategy and approved the

final version. Search results were imported for screening and further reviewing in Covidence systematic review software 2020, Veritas Health Innovation, Melbourne, Australia, where duplicates were identified and removed.

Studies of any design on rehabilitative, non-surgical, non-pharmacological treatment for patients of all ages with moderate-to-severe ABI with dysphagia in the first 6 month from injury were eligible for inclusion.

The following criteria for moderate-to-severe ABI was used; The National Institute of Health Stroke Scale (NIHSS) >15; Glasgow Coma Scale (GCS) <9[22]; Barthel Index <60; Functional Independence Measure (FIM) ≤54; Modified Rankin Scale (MRS) ≥4.[29]

Corresponding authors of studies that could not be assessed for eligibility due to missing data on brain injury severity were contacted to obtain this information.

Three authors (SJE, IP and DJC) independently screened title and abstracts of all retrieved citations against the detailed inclusion and exclusion criteria.[22] If disagreement occurred, consensus was achieved through discussion between the four authors (SJE, DJ, IP and DJC). Prior to screening n=30 title and abstracts were reviewed to ensure agreement on interpretation of the eligibility criteria and approach to screening.

Three authors (SJE and DJC) independently extracted prespecified data from included studies in a chart based on the protocol. Two reviewers verified each extraction. DJ extracted data from German language studies.

Stages 4 and 5: charting the data, collating, summarising and reporting the results

Data on: *general information* (title, authors, country, contact information, year, language); *methods* (design, setting); *interventions* (type, timing, dose, duration, control if any); *participants* (n, demographics); and *outcome measures* was extracted and collected in a table.

The studies were categorised based on treatment modality as well as subgroup diagnosis and age-group, (paediatric (0–17 years) and adults, respectively). Treatment interventions were categorised in two main categories based on previous literature: (1) interventions that used direct brain stimulation (cortical); (2) interventions that used indirect brain stimulation (non-cortical)[18] and divided into subgroups based on the type of intervention.

In addition, outcome measures used in included studies are presented, as well as the reported results from the studies. First, a numeric analysis was conducted and second, a qualitative descriptive analysis of the findings.

Stage 6: consultation with stakeholders

The Danish Society for Dysphagia, the European Society for Swallowing Disorders (ESSD), the Society of Occupational Therapy for Dysphagia (DK), as well as key informants Rainer Seidl (Germany), Olle Ekberg (Sweden), Renée Speyer (Norway) and Ulrike Frank (Germany) were contacted by mail to identify potential missing or ongoing relevant studies or interventions that were not retrieved in the review process.

Patient and public involvement

There has been no patient or public involvement in addition to the key informants.

RESULTS

A total of 21 396 records were retrieved from database searches. Additional searches produced no new records, and consultation with stakeholders produced 33 additional records. After removing duplicates, 16 180 abstracts were screened for eligibility and subsequently 344 articles were assessed in full-text. Due to language restrictions, 61 studies were excluded. Corresponding authors of 73 studies were contacted, where the ABI severity was not stated. None of the inquiries yielded further information on severity and we therefore chose to exclude these studies. A final 26 studies were included. Figure 1 PRISMA flowchart.

Of the 26 included studies and trials, 18 are randomised controlled trials (n=10 to n=306),[30–47] one is a non-randomised controlled trial (n=24),[48] three are cohort studies (n=24 to n=208),[8 49 50] two are case series[51 52] and two are case reports.[53 54] The studies are published between 1998 and 2020.

Numerical analysis

Table 1 presents the characteristics of included studies in detail.

The 26 studies had a total of 1601 patients included. In 17 studies the patients had dysphagia following stroke.[31–34 36–42 44–46 48 52] Three studies included only patients with traumatic brain injury (TBI)[8 30 54] and four included patients with stroke and patients with TBI.[35 43 47 51 53] Bath *et al* also included patients with both stroke and TBI, but only the TBI subgroup met our inclusion criteria and was included.[49] One study also included patients with head and neck cancer and degenerative neurological diseases in addition to acute ABI.[50] All studies were set in a hospital or acute or subacute rehabilitation units.

One study included children with ABI (n=60),[30] the remaining included adults with ABI.

Studies were conducted in Germany (n=5), Korea (n=3), Denmark (n=2), Egypt (n=2), Australia (n=1), China (n=1), Greece (n=1), Iran (n=1), Italy (n=1), Japan (n=1), Spain (n=1), Sweden (n=1), Taiwan (n=1), Thailand (n=1), UK (n=1), USA (n=1), one multicentre cohort study included patients in Austria, Germany and the UK, and a multicentre RCT included patients in Austria, Germany and Italy.

The swallowing assessment used as the inclusion criterion varied between studies: 5 studies used clinical assessment,[30 39 46 47 52] 2 studies used a dysphagia screening tool,[34 45] 2 studies based inclusion on oral intake[38 42] and 16 studies used instrumental assessment by fibreoptic endoscopic evaluation of swallowing or Videofluoroscopic

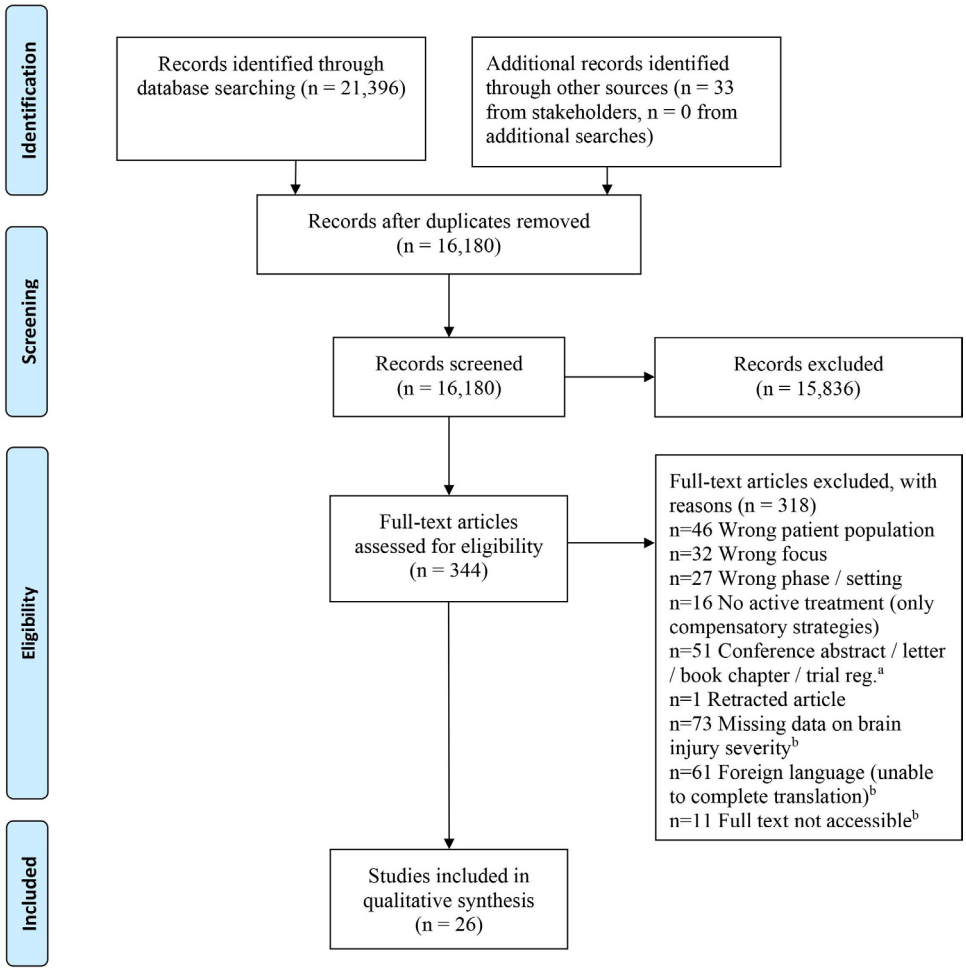

Figure 1 Preferred Reporting Items for Systematic reviews and Meta-Analysis flowchart. [a]were unable to assess eligibility, [b]awaiting classification

Swallow Study.[31–33 35–37 40 41 43 44 47–51 54] One study did not report on the method for initial dysphagia assessment.[53]

Qualitative syntheses

The interventions can be categorised into the two main treatment modalities, *cortical* or *non-cortical* stimulation of the swallowing network (figure 2).

Cortical interventions

Two interventions were defined as cortical stimulation interventions: Repetitive transcranial magnetic stimulation (rTMS), and transcranial direct current stimulation (tDCS). *Cortical stimulation interventions* are aimed at direct cortical stimulation of the brain and subcortical swallowing network. rTMS modulates cortical excitability by focally stimulating the cortical region. The studies in this review used rTMS to stimulate specific cortical motor areas associated with swallowing. The studies applied rTMS in varied modes. Khedr *et al* used 3 Hz rTMS on the oesophageal cortical motor area of the affected hemisphere[34] and Lee *et al* applied 10 Hz to the cortex representing the suprahyoid muscle of the affected side.[48] The remaining three studies targeted the mylohyoid muscles, with Tarameshlu *et al* applying 1 Hz to the undamaged cerebral hemisphere,[42] Kim *et al* tested 5 Hz to the affected hemisphere[35] and Park *et al* using 10 Hz bilaterally.[37]

Non-invasive tDCS is a cortical stimulation technique aimed at the recovery of swallowing functions by expansion of the pharyngeal representation in the undamaged hemisphere, hypothetically ensuring increased input to the brainstem swallowing centres. Current stimulation aims to facilitate this process in patients with hemispheric lesions without brainstem damage.[36 39] One study applied anodal tDCS over the lesioned hemisphere and cathodal stimulation to the contralesional, aiming to restore output from the lesioned side and counteract a suppressive effect from the contralesional hemisphere.[39] The second study used anodal tDCS to the unaffected hemisphere.[36] The stimulation was applied during concurrent swallowing therapy.[36 39]

Non-cortical interventions

Non-cortical interventions are treatments aimed at improving swallowing by augmenting sensory input to the swallowing network in the brain, causing increased activity in the motor swallowing areas in the cortex, neural network and brain stem.[18]

Table 1 Included studies

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Abusaad[30]	2012	RCT	Modification of the manner of feeding, positioning and posture change for safe swallowing, oral-motor exercises and controlling of drooling	5 days per week for one month	Parental or enteral feeding	n=60 (30/30). TBI (GCS 4–8) Intervention: mean age 6.33±2.4, M/F 14/16. Control: mean age 6.23±2.9, M/F 12/18	Improvement in feeding domains: spoon feeding, biting, chewing, cup-drinking, drooling	0 month, 1 month	Significant improvement in the feeding domains of spoon feeding, chewing, cup drinking and drooling in the intervention group	Complex swallowing interventions
Carnaby[32]	2006	RCT	Low intensity (compensation strategies, mainly environmental modifications) or high intensity (direct swallowing exercises for example, effortful swallowing, supraglottic swallow technique)	Low intensity: 3 times per week for 1 month (or length of stay if less). High intensity: every working day for a month (or length of stay if less). Usual care: when eating and drinking.	Usual care—supervision for feeding and precautions for safe swallowing (eg, positioning, slowed rate of feeding)	n=306 (102/102/102) stroke (per protocol n=243 at 6 months). Barthel index <15: 80 (78%) / 80 (78%) / 81 (79%) Mean age 71 years, M/F 178/128	Normal (prestroke) diet	6 months	No effect of standard programme of swallowing therapy on survival, free of abnormal diet (restricted consistency or special preparation for safe intake) at 6 months	Complex swallowing interventions
Hansen[8]	2008	Retrospective cohort study	F.O.T.T.—individually planned	Number of therapy sessions determined by patient's overall condition, severity of impairments and responses to the interventions	None	n=173 Severe TBI. Median age 35 years (IQR 24–51 years), M/F 168/45	FOIS	At discharge and follow-up six months after discharge	110 (64%) returned to unrestricted dieting (FOIS score 7) before discharge. Of the 63 (37%) patients with an FOIS score less than 7 at discharge, half were dependent on a PEG tube.	Complex swallowing interventions
Jakobsen[47]	2019	Pilot RCT	Nonverbal facilitation of swallowing and stimulating activities in the facial oral tract	30 treatments over 3 weeks (two treatments daily) in addition to daily rehabilitation programme, which included F.O.T.T. Each treatment consisted of a 10 min rest period followed by a 20 min intervention and a further 10 min rest.	Stimulating activities in the facial oral tract but without facilitation of swallowing or verbal request to swallow.	n=10 (5/5). Severe stroke/TBI (GCS<9) Intervention: mean age 45.6 years (range 37.5–57.8). Control: mean age 53.8 years (range 41.8–61.4). M/F 6/4	FOIS, PAS, and electrophysiological swallowing specific parameters	End of treatment (3 weeks)	PAS and FOIS scores improved in both groups, with no differences between groups. The swallowing specific parameters reflected clinically observed changes in swallowing.	Complex swallowing interventions

Continued

Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Nusser-Müller-Busch[54]	2004	Case report	Tracheal tube management and F.O.T.T.	Daily treatment for 4 months, starting 4 weeks after the accident.	None	n=1 Severe TBI 56 years, M	BDI evaluated with FEES	4 months	BDI score 74 (start of intervention) to 2 (end of intervention), fully enteral nutrition to removal of PEG and from cuffed tube to none	Complex swallowing interventions
Seidl[51]	2007	Case series	Neurophysiological dysphagia therapy/ F.O.T.T.	15 sessions of 60 min in 3 weeks	None	n=10. Severe stroke/ TBI+tracheostomy. (Frürehab BI −175.00±0.00). Mean age 39.17±20.5 years. M/F 6/4	Swallowing frequency. FEES and aspiration (PAS, BDI)	At 3 weeks/end of treatment. End of daily treatment and 30, 60, 90, 120 min after completing the treatment session	Statistically significant increase swallowing frequency over the entire therapy period. Changes in swallowing ability and protection of the lower respiratory tract recorded over the course of the therapy were statistically significant on all consistencies. BDI: Baseline= 50.71±7.61; End= 14.00±12.82 (p<0.001) PAS (saliva) (1-8): baseline=8±0; End=0.75 ± 1.49 (p=0.017)	Complex swallowing interventions
Welter[53]	1998	Case report	F.O.T.T., speech and language therapy, Bobath, Affolter	Not reported	None	n=2: (A), basilar thrombosis, 33 years, F; (B), traumatic brain injury and anoxia, 30 years, M. (BI 10/25)	Removal of nasogastric tube and eating	At discharge	A: nasogastric tube removed and eating by mouth B: PEG tube not removed and no oral intake	Complex swallowing interventions

Continued

Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Xia[44]	2016	RCT	Combined swallowing training and acupuncture methods	30 mins per session, 6 sessions/week for 4 weeks	Functional training applied to the 'feeding and swallowing organs'. This included active or passive exercise of the oral, facial, and lingual muscles, sensory stimuli, and some specialised methods such as the Mendelsohn manoeuvre, supraglottic and superglottic manoeuvres, swallowing efforts, and the Shaker exercise.	n=124 (62/62) Stroke (per protocol 60/60). MBI scores 52.3 (15.7)/ 53.1 (16.3). Mean age 65.7 (14.2). M/F 71/53	SSA and DOSS rating scale based on VFS.	SSA each week of treatment over a 4-week period. The DOSS after the 4 weeks of treatment.	No difference between the groups in SSA at 1 week. After 4 weeks SSA and DOSS significantly improved in the acupuncture group ($p<0.001$)	Complex swallowing interventions
Permsirivanich[38]	2009	RCT	NMES	60 mins, 5 days per week for 4 weeks	Rehabilitation swallowing treatment (RST)	n=23 (12/11). Stroke. Admission Barthel activities of daily living index1 38.64±16.75/ 40.83±16.35. Mean age: NMES 64.5±8.8; RST 64.7±9.4, M/F 9/14.	FOIS	Baseline and end of treatment (4 weeks)	The mean changes in FOIS scores were 2.46±1.04 for the RST group and 3.17±1.27 for the NMES group ($p<0.001$).	NMES

Continued

Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Terré[43]	2015	RCT	NMES using Vital Stim and conventional swallowing therapy, changes in diet and active manoeuvring, motor control exercises.	45 mins electrical stimulation per session, 20 sessions of 60 mins during 4 weeks.	Sham electrical stimulation (ShES) and conventional swallowing therapy.	n=20 (10/10). Stroke/ severe TBI FIM NMES:40 (20–82), ShES:48 (26–80) Mean age 48, range 22–69. M/F 12/8	FOIS	Baseline, end of treatment (1 month) and 3 months follow-up	Mean FOIS score before treatment was 1.9 for the NMES group and 2.1 for the SES group. After treatment, the NMES group increased by 2.6 points (4.5 points) compared with only 1 point (3.1 points) for the ShES group (p=0.005). At 3 months of follow-up, mean scores were 5.3 and 4.6, respectively; thus, both groups improved similarly.	NMES
Bath[31]	2016	RCT	PES	10 mins per day for three consecutive days	Sham	n=162 (87/75). Stroke. (per protocol 70/56) BI 32.4±31.7) / 23.8±26.8. Intervention: mean age 74.4±11.2 years, M/F 48/39) Control: mean age 74.9±12.6 M/F 46/29.	Swallowing safety, assessed using the PAS based on VFS	2 weeks (primary), 6 weeks, 12 weeks	No significant difference. PAS 3.7±2.0 in the PES group and 3.6±1.9 in the control group (p=0.60)	PES
Bath[49]	2020	Cohort study	PES—nasogastric feeding tube with built-in stimulation electrodes. Stimulation at 5 Hz.	10 mins per day for three consecutive days	None	n=24 (subgroup) TBI (GCS 10.5±4). Mean age 62.2±16.4 years. M/F 19/5	DSRS based on FEES. Additional outcomes FOIS and PAS	3 months post-treatment	Significant improvement from baseline to 3 months post-treatment on DSRS for n=20 patients (per protocol analysis).	PES
Dziewas[33]	2018	RCT	PES	10 mins per day for 3 days	Sham PES	n=69 (35/34). Stroke. Intervention: 61.7±13 years. M/F 24/11 Control: 66.8±10.3 years. M/F 20/14	Readiness for decannulation 24–72 hours after treatment	End of treatment (3 days)	OR 7 (95% CI 2.41 to 19.88) in favour of PES group	PES

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Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Suntrup[41]	2015	RCT	PES via nasogastric catheter.	10 mins per day for three consecutive days	Sham EPS	n=30 (20/10). Severe stroke, tracheostomy (post ventilation) NIHSS mean (SD) 17.45 (7.1). Mean age PES: 63.0±14.5, Sham: 66.7±14.5 years. M/F 15/15.	Ability to decannulate the patient, facilitated by improved swallowing function based on FEES assessment	End of treatment (3 days)	After PES 15 out of 20 patients (75 %) of the stimulation group and 2 out of 10 patients (20 %) of the control group could be successfully decannulated within 72 hours after finishing study treatment (p<0.01).	PES
Khedr[34]	2009	RCT	rTMS	300 rTMS pulses per day for 5 days	Sham rTMS	n=26 (14/12). Stroke. (BI 30/20) Mean age: rTMS: 58.9±11.7 years, Control: rTMS: 56.2±13.4 years M/F 10/16	DOSS	Pre, post, 1 month, 2 months.	Real rTMS led to a significantly greater improvement compared with sham in dysphagia and motor disability that was maintained over 2 months of follow-up. Significant increase in the amplitude of the oesophageal MEP evoked from either the stroke or non-stroke hemisphere.	rTMS
Kim[35]	2011	RCT	Low or high frequency rTMS	20 mins per day, 5 days per week for 2 weeks.	Sham	n=30 (10/10/10). Acute brain injury. High frequency: K-MBI 13.0±14.2 mean age 69.8±8.0 years, M/F 5/5. Low frequency: K-MBI 15.6±20.9, mean age 66.4±12.3 years, M/F 6/4. Sham: K-MBI 11.4±13.8), mean age 68.2±12.6 years, M/F 6/4.	FDS and PAS with VFSS and ASHA NOMS	Baseline, post-treatment (2 weeks)	Low frequency improved FDS and PAS but not ASHA NOMS. No significant effect of high frequency and sham.	rTMS

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Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Lee[48]	2015	Non-randomised control study	rTMS of the cortex representing suprahyoid muscle	10 secs every min, 10 mins per day for 10 days	rTMS cortex representing abductor policis brevis	n=24 (12/12). Stroke. (K-MBI 47.0±6.1/50.6±7.7). Suprahyoid group: mean age 66.1±11.2 years, M/F 7/5. Abductor policis group: mean age 60.9±11.4 years, M/F 10/2	FDS, PAS, DOSS	Pre, post, follow-up (4 weeks)	No significant group×time interactions for any outcomes	rTMS
Park[37]	2017	RCT	High-frequency rTMS, bilateral or unilateral stimulation and conventional dysphagia therapy	Ten consecutive rTMS sessions during 2 weeks plus 30 mins conventional therapy	Sham stimulation	n=33 (11/11/11). Stroke. K-MBI: Bilat: 12.8±20.7, Unilat: 7.36±19.7, Conventional: 6.64±19.7. Mean age 65.9±12.4 years. M/F 23/10	VFSS with PAS and the VDS, CDS, DOSS.	T0, pre-intervention; T1, post-intervention and T2, 3 weeks post intervention	There was a significantly larger change in the DOSS, PAS, and VDS scores at T1 in the bilateral stimulation group than in two other groups. In the bilateral and unilateral stimulation groups, all CDS, DOSS, PAS, and VDS scores significantly improved over time ($p<0.05$). In the sham stimulation group, except for CDS at T1, the DOSS, PAS, and VDS scores improved over time ($p<0.05$)	rTMS
Tarameshlu[42]	2019	Pilot RCT	rTMS; traditional dysphagia therapy (TDT)—rehabilitative (oromotor exercises, sensory stimulation, and swallowing manoeuvres) and compensatory strategies; combined intervention (CI)—rTMS +TDT	TDT group: 18 sessions of treatment, 3 x/week for 6 weeks. rTMS group: daily for five consecutive days. CI group: rTMS daily for five consecutive days combined with the TDT, 18 sessions of treatment, 3 x/week for 6 weeks.	Three arms - control TDT	n=18 (6/6/6)). Stroke. BI median (IQR): rTMS group: 24.17 (4.91) TDT group: 46.67 (21.37) Combined intervention group: 50 (31.62). Mean age 65.3 years. M/F 9/9	MASA	The MASA and FOIS were measured before treatment (T0), after the fifth session (T1), after the 10th session (T2), after the 15th session (T3), and after the 18th session (T4).	All groups had improved on MASA and FOIS scores over time ($p<0.01$). The improvements achieved in all outcomes were significantly greater in the CI group than those of the TDT and rTMS groups.	rTMS

Continued

Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Kumar[36]	2011	RCT	Anodal tDCS with concurrent standardised swallowing manoeuvres	30 mins/day for five consecutive days	Sham	n=14 (7/7) Stroke. NIHSS median 15.5 (range 6–21) tDCS group: mean age 79.7 years, M/F 3/4. Sham group: n=7, mean age 70 years, M/F 4/3	DOSS	Pre and post	Significant improvement in DOSS in tDCS group compared with sham.	tDCS
Pingue[39]	2018	RCT	tDCS. 2 mA of anodal tDCS over the lesioned hemisphere and cathodal stimulation to the contralesional plus swallowing training consisting of direct therapies (including compensatory methods, behavioural manoeuvres, supraglottic and effortful swallowing) and indirect approaches (physical manoeuvres, thermal tactile stimulation)	30 mins/day for 10 days	Sham stimulation plus conventional therapy	n=40. Stroke FIM-motor median 13.5 (IQT 13–18) FIM-cognitive 10.5 ((5–14.25) Median age 66 (IQR 55.75–73.25) years, M/F 20/20	DOSS score and PAS with VFS with a 10 mL bolus of liquid and semiliquid, and solid gastromiro-containing foods	Dysphagia was assessed 1 week before and 1 week after completion of the treatment protocol	No significant differences between the two groups (p>0.05) on DOSS or PAS or percentage of patients with clinically relevant improvement.	tDCS
Hamada[52]	2017	Retrospective control case series	General dysphagia/ surface sensory e-stim combination therapy	Not reported	General dysphagia therapy	n=53 (18/35). Stroke E-stim group: NIHSS 13.3±5.3. Mean age 75±4.2 years, M/F 10/8. Control group: NIHSS 13.3±8.1. Mean age 77.9±7.2 years, M/F 20/15,	Pulmonary infection: presence of fever, cough, and purulent sputum, abnormal findings on chest radiography and/ or CT	During stay at the stroke unit	Significant fewer, pulmonary infections in e-stim group	Sensory stimulation
Prosiegel[50]	2002	Prospective cohort study	Thermostimulation, change of position, modification of consistencies, exercises for tongue		None	n=208. Neurological patients (acute and degenerative) and patients with head and neck cancer. Mean BI (range) 58 (0–100) Mean age 59.5 years (18-86), M/F 64/36	Unpublished scales for oral nutrition and aspiration	Start and end of intervention	55% changed from non-oral to oral nutrition, 44% with tracheal tube had the tube removed	Sensory stimulation

Continued

Table 1 Continued

First author	Year	Design	Type of intervention	Timing, dose and duration of intervention	Control intervention	Demographics (n (I/C), population, age, sex)	Primary outcomes for swallowing ability/function	Timing of outcome measures	Results	Categorisation of intervention
Hägglund[45]	2020	RCT	Oral neuromuscular training using an oral device (Muppy) plus orofacial sensory-vibration stimulation	Three times/session, three times daily before eating	Orofacial sensory-vibration stimulation with electric toothbrush	n=40 (20/20) Stroke (NIHSS not complete, but several with moderate-severe stroke). (per protocol 10/9). Mean age 75 years (range 56–90), M/F 25/15	Changes in swallowing rate measured by TWST. Additionally lip force and swallowing function based on VFS	5 weeks and 12 months post-treatment	At 5 weeks there was no significant difference between groups. At 12 months post-treatment, the swallowing rate had improved significantly in the intervention group compared with the control group (p=0.032)	Strengthening exercises (cervical, oral device facilitated)
Ploumis[40]	2018	RCT	Cervical isometric strengthening exercises using manual resistance in all four directions plus standard treatment	Four repetitions for 10 mins, three times a day for 12 consecutive weeks	12 week regular inpatient therapeutic programme, including physiotherapy, occupational therapy and speech-language therapy. The speech language programme lasted 30 min daily and included deglutition muscle strengthening and compensatory techniques training	n=70 (37/33). Stroke (BI 15.6±3.2). Mean age 52±15 years, M/F 53/17	VFSS. deglutition was rated on a scale of 0–2, with value 0 presenting normal deglutition, 1 showing signs of retention and penetration and two depicting aspiration (value 0 represents score 1, value 1 represents score 2–5 and value 2 represents score 6–8 of the validated 8-point PAS)	End of treatment 12 weeks	Significantly greater improvement in VFSS scores for the intervention group compared with standard treatment (p<0.001)	Strengthening exercises (cervical, oral device facilitated)
Liaw[46]	2020	RCT	Combined inspiratory and expiratory respiratory muscle training using the Dofin Breathing Trainer (DT 11 or DT 14 GaleMed Corporation) plus regular rehabilitation	Five sets of five repetitions, 5 days a week for 6 weeks plus regular rehabilitation.	Regular rehabilitation (postural training, breathing control, improving cough technique, fatigue management, orofacial exercises, thermal tactile stimulation, Mendelsohn manoeuvring, effort swallowing, or supra-glottic manoeuvre)	n=31 (15/16). Stroke (BI 27.26±18.97). Mean age 62.8±11.2 years, M/F 12/19	Change in maximal inspiratory pressure (MIP) (cmH_2O) and maximal expiratory pressure (MEP) (cmH_2O). For MIP, negative pressure is favourable and for MEP, positive pressure is favourable. Swallowing specific outcomes: FOIS	End of treatment (6 weeks)	No significant difference between the groups over time for FOIS	Respiratory muscle training

ASHA NOMS, American Speech-Language Hearing Association National Outcomes Measurements System Swallowing Scale; BDI, Berlin Dysphagia Index; BI, Barthel Index; CDS, Clinical Dysphagia Scale; DOSS, Dysphagia Outcome and Severity Scale; DSRS, Dysphagia Severity Rating Scale; FEES, fiberoptic endoscopic evaluation of swallowing; FOIS, Functional Oral Intake Scale; F.O.T.T., Facial Oral Tract Therapy; I/C, intervention/control; K-MBI, Korean version of modified Barthel Index; M/F, male/female; NMES, neuromuscular electrical stimulation therapy; PAS, Penetration Aspiration Scale; PEG, percutaneous endoscopic gastrostomy; PES, pharyngeal electrical stimulation; RCT, randomised controlled trial; rTMS, repetitive transcranial magnetic stimulation; SSA, standardised swallowing assessment; TBI, traumatic brain injury; TWST, timed water-swallow test; VDS, Videofluoroscopic Dysphagia Scale; VFS, videofluoroscopy.

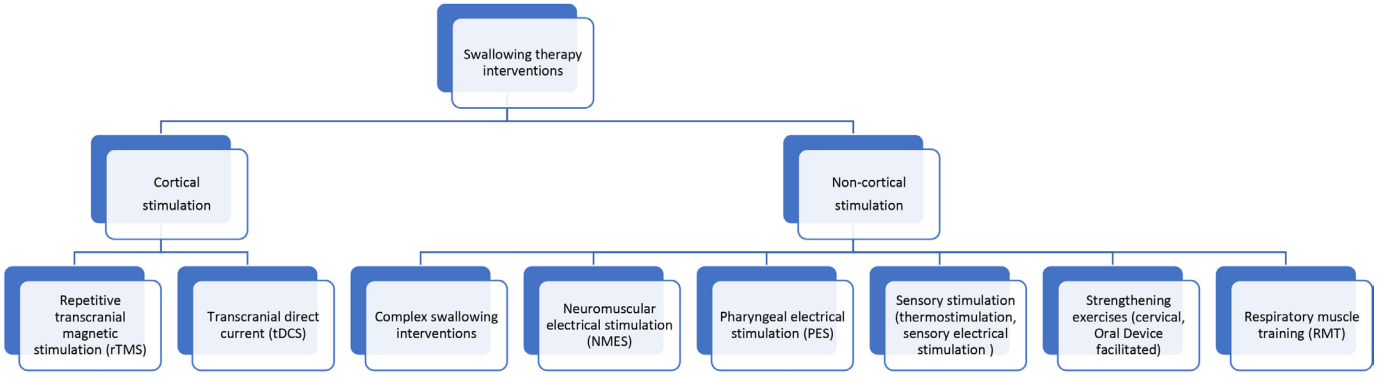

Figure 2 Categorisation of swallowing therapy interventions in included studies.

Six categories were defined for mapping the non-cortical interventions: complex swallowing interventions, neuromuscular electrical stimulation (NMES), pharyngeal electrical stimulation (PES), sensory stimulation (including sensory electrical stimulation (SES), thermo-stimulation and thermal/tactile stimulation), strengthening exercises and respiratory muscle training.

Three studies combined interventions consisting of direct exercises and/or manoeuvres and compensation strategies, including positioning, posture change and dietary modification.[30 32 44] Swallowing exercises aim at altering swallowing physiology and promoting long-term changes, and can involve strengthening impaired oropharyngeal musculature through oropharyngeal exercise, using oropharyngeal swallowing manoeuvres (some are both a compensatory strategy and rehabilitative exercise), and increase sensory input through thermal–tactile stimulation.[55 56] Carnaby *et al* tested the intervention at low and high intensity against usual care,[32] while Xia *et al* tested acupuncture as an add-on to a combined intervention.[44] Three descriptive case studies examined Facial Oral Tract Therapy (F.O.T.T.), an interdisciplinary complex rehabilitation intervention that aims to re-establish facial oral functions in everyday life activities, using principles for motor learning.[57–59] One pilot RCT study tested the effect of intensified non-verbal facilitation of swallowing during F.O.T.T.[47] and one study examined the effect of F.O.T.T. on time to unrestricted diet in a cohort.[8]

Two studies tested NMES,[38 43] a treatment used to strengthen muscle groups with preserved motor innervation, targeting strengthening of the oropharyngeal musculature to improve swallowing physiology. It is also hypothesised to provide sensory feedback to the central nervous system to facilitate swallowing response.[60] Terré and Mearin placed electrodes horizontally in the submental region over the mylohyoid muscle (suprahyoid) with the lower set placed on the skin either side over the thyroid cartilage.[43] Permsirivanich *et al* described the electrode placement as 'midline 1 mm above the thyroid notch, the second electrode immediately superior to the first, the third electrode 1 mm below the thyroid notch and the fourth electrode immediately inferior to the third'. The strength of stimulation was "based on the subjects' verbal feedback'.[38] Both NMES studies used a stimulation frequency of 80 Hz.

PES was tested in four studies.[31 33 41 49] Like NMES, PES targets the peripheral neuromuscular system and aims to strengthen the impaired oropharyngeal musculature. In two studies, patients had tracheostomies, and decannulation was the main outcome.[33 41]

In two studies, different sensory stimulation interventions were assessed.[50 52] Hamada *et al* studied surface SES in combination with general dysphagia therapy. Electrodes were placed horizontally in the submental region over the mylohyoid muscle above the hyoid bone. The amplitude of the electrical current was set to the sensory threshold level at which the patients reported a tingling sensation on the skin.[52] Hypothetically SES induces neuroplastic changes in the sensory cortex, but the exact mechanism is unknown.[52] Prosiegel *et al* assessed thermo-stimulation combined with change of position, modification of consistencies and tongue exercises.[50] The intervention aimed to trigger the swallowing reflex through thermo-stimulation.

One study tested an intervention of cervical strengthening exercises against resistance in four directions.[40] The treatment aimed to improve posture by keeping the head in alignment in an upright position, the shoulders horizontal and activating muscles of mastication. Another study tested oral neuromuscular training with an oral device (Muppy) aimed at stimulating sensory input and strengthening the facial, oral and pharyngeal muscles.[45]

The final study was categorised as respiratory muscle training (RMT) with a hand-held threshold trainer and investigated the feasibility and efficacy of a combined inspiratory and expiratory muscle training on pulmonary dysfunction and swallowing function.[46]

The outcome measures of the studies are categorised and presented in table 2.

Summary of reported results by intervention subcategories

Four studies on rTMS with sham control groups found some improvement in favour of the intervention,[34 35 37 48] the remaining study on rTMS found a better effect of rTMS combined with traditional dysphagia therapy than rTMS or traditional therapy alone.[42] Results on tDCS are

Table 2 Dysphagia outcome measures applied in included studies

Dysphagia outcome	Outcome measures (studies)
Dysphagia severity	FDS[34 36 37 39 44 48] DOSS[49] DSRS[51 54] BDI[37] VDS[37] CDS[51]
Swallowing ability/ efficiency	Swallowing frequency[44] SSA[42] MASA[45] TWST[30]
Oral intake	Improvement in Feeding Domains[32] Return to pre-stroke diet[35] ASHA NOMS[38 43 46 47 49] FOIS[50] Custom-made scales for oral nutrition[53] Removal of nasogastric tube and eating[31 35 37 39 40 45 47–49]
Swallowing safety, penetration/ aspiration Airway complications	PAS[50]; Aspiration[52] Pulmonary infection[33]
Decannulation	Readiness for decannulation[64]

ASHA NOMS, American Speech-Language Hearing Association National Outcomes Measurements System Swallowing Scale;[65] BDI, Berlin Dysphagia Index;[66 67] CDS, Clinical Dysphagia Scale;[68] DOSS, Dysphagic Outcome and Severity Scale;[69] DSRS, Dysphagia Severity Rating Scale; FEES, fibreoptic endoscopic evaluation of swallowing; FDS, Functional Dysphagia Scale;[70] FOIS, Functional Oral Intake Scale;[71] MASA, Mann Assessment of Swallowing Ability;[72] PAS, Penetration Aspiration Scale;[73 74] SSA, Standardised Swallowing Assessment;[75] TWST, Timed Water-Swallow Test; VFS, videofluoroscopy; VFSS, Videofluoroscopic Swallowing Study; VDS, Videofluoroscopic Dysphagia Scale.[75]

inconsistent. One shows effect on Dysphagia Outcome Severity Scale (DOSS) compared with sham, the other no difference between groups on DOSS or Penetration Aspiration Scale (PAS).[36 39]

For the complex swallowing interventions using combined exercise and compensatory intervention, the results are also inconsistent. Carnaby *et al* found no significant difference between groups,[32] while the study by Abusaad and Kassem showed an improvement in feeding domains for children after a 1-month intervention.[30]

Three studies on F.O.T.T. were case studies/series that found increased oral intake and improved safety of swallowing.[51 53 54] Hansen *et al* also found improvement in oral intake using Functional Oral Intake Scale (FOIS) in a retrospective cohort.[8] Jakobsen *et al* found improved scores for PAS and FOIS in both groups, but no significant difference between groups after non-verbal facilitation of swallowing in an RCT.[47] Xia *et al* found no difference at the end of treatment for acupuncture as an add-on to standard dysphagia therapy, but did find a significant difference in favour of the intervention group with improvement in dysphagia severity at 4 weeks follow-up.[44]

Overall, the two RCT studies on NMES found no difference between intervention and control, but both had active control groups.[38 43]

Of the three RCT studies on PES, two found effect on decannulation,[33 41] the third found no difference between intervention and control on PAS.[31] Bath *et al* found significant improvement from baseline to 3-month post-PES treatment on the Dysphagia Severity Rating Scale for 20 patients in a per-protocol analysis in a subsample of patients with TBI.[49]

The two studies on sensory stimulation and conventional dysphagia therapy reported mixed results.[50 52] Hamada *et al* found fewer pulmonary infections after SES in a retrospective cohort study.[52] Prosiegel *et al* found positive changes in oral intake and decannulation after thermo-stimulation in a prospective cohort study.[50]

The RCT study on cervical strengthening exercises found improved oral intake at end of treatment (12 weeks)[40] and the RCT study from Hägglund *et al* found that oral neuromuscular training using an oral device (Muppy) improved swallowing rate at 1 year, but not at 5 weeks follow-up.[45]

Liaw *et al* found no significant difference between the groups over time on FOIS in an RCT comparing regular rehabilitation with and without RMT.[46]

DISCUSSION

This scoping review presents a summary of rehabilitative dysphagia interventions reported in the literature in patients with moderate-to-severe ABI. We identified two major categories of interventions, cortical and non-cortical stimulation and eight subcategories based on treatment modality: rTMS; tDCS; complex swallowing interventions; NMES; PES; sensory stimulation (including SES, thermo-stimulation and thermal/tactile stimulation), strengthening exercises and respiratory muscle training.

A scoping review was chosen in preference to a systematic review to ensure a broad scope in a sparse research field and because we wished to include all study types and designs as well as grey literature, in order to identify all the relevant interventions that have been published.[61] We could also see great value in the validation and consulting stage with key experts in the field, which did in fact lead to the inclusion of additional studies.

We chose to categorise the interventions identified in this review in a similar way to those in the most recent Cochrane review (2018) on swallowing therapy for dysphagia in acute and subacute stroke.[18] Unlike the Cochrane review, we did not include studies on patients with mild injuries. Nevertheless, some of the interventions investigated in the Cochrane review that do not require active participation were also included in this scoping review. Furthermore, we chose to include all study designs as our focus was not on the effect of treatment. Instead, we scoped the field of dysphagia interventions, and found additional categories of

complex swallowing interventions, that were not examined in the above-mentioned Cochrane review. Our review identifies additional studies focusing on strengthening exercises, complex dysphagia interventions and studies that have been published after 2018.

Many of the interventions identified in this review (rTMS, tDCS, NMES, PES, SES, oral neuromuscular training, RMT) require purchase of specific equipment and specialised training for correct and safe performance. Training requirements and equipment cost can be a barrier to the implementation of these interventions in routine clinical practice.

It is apparent from the included studies that any form of evidence synthesis would be difficult. The interventions not only vary in intensity and duration but also in the nature of the intervention, for example, placement of electrodes, stimulation frequency, intensity and mode. Usual treatment is used in many studies with the study intervention as an add-on. Usual treatment is often described by a list of interventions with no description of the dose, intensity, application or timing of the different components. Future studies should emphasise the description of standard care.

Outcome measures are also diverse and may reflect the rehabilitation phase, injury severity or even the setting. In order to allow for a meaningful evidence synthesis, there is a need to establish consensus on reliable and valid core outcomes for dysphagia in this population.

Furthermore, observational studies are prone to overestimate the effect size.[62] Even those studies showing an effect should be interpreted with caution.

Many studies do not report brain injury severity but only dysphagia severity. This makes it difficult to assess the applicability and effect of the intervention on a given patient and could complicate or hinder implementation of an intervention in the clinical setting. For example, some of the included interventions require the patients' active participation in performing specific exercises. This would exclude patients with severe ABI and disorders of consciousness. The effect of the intervention may also vary between patients with moderate and severe brain injury and be depended on the type of injury. These details should be consistently reported in future studies, along with patient characteristics on consciousness, cognition and participatory ability.

Strengths and limitations

This review has several limitations. First, missing data on brain injury severity in several studies led to excluding some possibly relevant studies. This information was often unavailable from the corresponding authors. Second, the timing of the assessment of brain injury severity was often not reported or consistent between studies, making it difficult to determine whether the study met the inclusion criteria. Third, the limitations due to necessary language restrictions caused the exclusion of Asian language papers, potentially excluding some relevant studies. Finally, given that the included studies have not been quality assessed, the summarisation of results should be interpreted with caution and cannot be directly applied to guide clinical practice.

The major strength of the scoping review is a comprehensive search, screening and selection of the literature using rigorous and transparent methods guided by the previously published protocol based on well-established methodology.[63] The review also included a comprehensive consultation process to ensure no relevant studies were overlooked.

CONCLUSION

This scoping review provides an overview of which non-surgical, non-pharmacological interventions are used in the rehabilitation of dysphagia in patients with moderate and severe ABI, predominantly patients who had a stroke, in the acute and subacute phase. Identifying two major categories of interventions, *cortical* and *non-cortical stimulation* and eight subcategories based on treatment modality: rTMS; tDCS; complex swallowing interventions; NMES; PES; sensory stimulation; strengthening exercises; and respiratory muscle training. Positive tendencies towards beneficial effects were found for rTMS, F.O.T.T, PES and cervical strengthening, although many of these studies are observational or case reports. Although not comparable across studies, results favoured rTMS over sham, case studies on F.O.T.T. showed improved swallowing safety and increased food intake, as did cervical strengthening exercises, while PES was found to improve time to decannulation. Results on tDCS and complex interventions were inconsistent, while studies on NMES and RMT found no difference between intervention and control. It is evident from the included studies, that any form of evidence synthesis would be difficult. Thus, based on this scoping review, we cannot recommend conducting a systematic review until further research is available. Future studies of rehabilitative interventions for dysphagia could benefit from clear reporting of patient diagnosis and disease severity, the use of more standardised treatment protocols or algorithms and fewer but standardised outcome measures to enable comparison of effects across studies and interventions.

Differences between protocol and review

Some adjustments to the selection criteria were required. The protocol stated no language restrictions, however, it was not possible to get an acceptable translation for the studies in Asian languages and consequently they were excluded. Not all studies reported brain injury severity, thus, the research group discussed additional cut-off values for determining severity by searching the literature. In addition to the NIHSS score and GCS already defined in our protocol article,[22] the following measures and definitions on severity were included: Barthel Index <60, FIM ≤54 and MRS≥4.[29] We did not state in our protocol how to assess studies that did not report brain injury severity. We decided to exclude studies in which brain injury severity could not be determined after contact to the corresponding author. Finally, we stated that two reviewers would independently extract data, however we changed this to one reviewer, and the data extraction was subsequently confirmed for accuracy by another reviewer.

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