

ORIGINAL PAPER

Improvement of swallowing function due to neuromuscular electrical stimulation in children with primary dysphagia

Ewa Winnicka¹, Katarzyna Kowalska¹, Julita Borkowska², Piotr Socha¹

¹Gastroenterology, Hepatology, Nutrition Disorders and Paediatric Department, Children's Memorial Health Institute, Warsaw, Poland

²Department of Neurology and Epileptology, Children's Memorial Health Institute, Warsaw, Poland

ABSTRACT

Introduction: Children suffering from primary dysphagia require enteral nutrition due to a lack of sufficient skills in oral feeding and swallowing. There are no data on neuromuscular electrical stimulation (NMES) in primary dysphagia treatment. Our aim was to identify possible changes in the swallowing function in children with limited cooperation and compare functional oral intake before and after NMES therapy.

Material and methods: A prospective study was performed to assess the effects of therapy among children with primary dysphagia and lack of progress in the development of swallowing function. The therapy was introduced for 30 minutes twice a day for 5 consecutive days. Such an intense cycle of therapy was repeated every one/two months. Each participant was scheduled for 10 therapeutic cycles. Evaluation was based on parents' and therapists' clinical observations, analysis of changes in several aspects of swallowing function, videofluoroscopic examination and the functional oral intake scale (FOIS).

Results: The studied group consisted of 34 children (mean age 33 months). Only 10 patients completed the full 10 cycles of therapy. The average number of cycles was 3.5 ± 2.3 . 23/34 patients improved their feeding abilities. There was a significant improvement on the FOIS scale [1 (1; 2) vs. 2.5 (2; 6); baseline vs. final; median (lower; upper quartile); $p < 0.0001$]. Additionally, we observed a positive change in the following aspects of swallowing function: effectiveness of defensive laryngeal reactions (15/34); control of saliva (9/34); reduction of gurgling breath (9/34); enhancement of facial and tongue muscle tonus (12/34); coordination between swallowing and breathing (6/34); initiation or increasing frequency of oral feeding (14/34).

Conclusions: Electrical stimulation improves functional oral intake. It may increase the frequency of oral feeding and reduce enteral nutrition regardless of the children's age at the beginning of the therapy.

KEY WORDS:

children, neuromuscular electrical stimulation, primary dysphagia, dysphagia treatment.

INTRODUCTION

Children suffering from feeding difficulties require enteral nutrition due to a lack of sufficient skills in oral feeding and swallowing. They need a nasogastric tube or gastrostomy tube for enteral nutrition, which tends to remain in place for years at a time – the median time for tube removal is 10 years [1].

Treatment of pediatric dysphagia can cause many difficulties for both parents and therapists, especially in cases of primary dysphagia, which entails a lack of cortical representation of swallowing function. It is vital to understand oral-motor dysfunction and its influence on primary dysphagia and, therefore, it will be helpful to explore some of the conceptual frameworks to review the current treatment of sensory-motor problems of swallowing.

ADDRESS FOR CORRESPONDENCE:

Dr. Ewa Winnicka, Department of Otolaryngology, Audiology and Phoniatics, The Children's Memorial Health Institute, Warsaw, Poland, e-mail: ewa.winnicka33@gmail.com

Children suffering from primary dysphagia are defined as a group of patients who never had normal swallowing or had a congenital condition known to be associated with dysphagia or an unknown condition with prenatal onset [2]. Swallowing is a function that involves the nervous system at many levels, using sensory-motor experiences. Traditional neural maturation theories propose a gradual cephalocaudal development, where cortical control follows a predetermined time course that eventually replaces neonatal reflexes [3]. When children with major physical and physiological problems are prevented from initial oral feeding in the same time frame as their more typically developing peers, many demonstrate prolonged delays and additional significant difficulty with oral feeding [4]. Some infants may become disorganized, exhibiting signs of fatigue with feeding progression. Infants with neurogenic dysphagia may also show increased disorganization as feeding progress [4]. The dynamic system theory proposes that motor development is a process of self-organization of many factors such as body weight, muscle strength, joint configuration, mood, environmental condition, and brain development [5]. It shows that swallowing is a function and not only a chain of reflexes. Examinations performed in adults using functional magnetic resonance imaging suggested bilateral activations in a large neural network, including the primary motor cortex, primary sensorimotor cortex, supplementary motor cortex, prefrontal cortex, Heschl's gyri, cingulate gyrus, insula, Broca's areas, and superior temporal gyrus [6, 7]. Other research indicated that pharyngeal components of swallowing (such as laryngeal closure) rely strongly on subcortical networks, whereas oral components of swallowing (such as tongue elevation) depend more on cortical sensorimotor cortex innervation [8, 9].

It is worth stressing that intellectual disability and communication disorders are important and frequent difficulties that significantly limit cooperation with children. It is very challenging to find a therapeutic method that can be used in children at an early age or in children whose cooperation is limited. Often, traditional or otherwise common swallowing therapy is impossible in such cases. Neuromuscular electrical stimulation (NMES) is a method used for adults with dysphagia after brain injury or cancer treatment, i.e., acquired dysphagia. This form of therapy can improve the trophic parameters of muscles involved in swallowing, as well as their endurance and strength, and can improve the sensory sensitivity of the swallowing reflexes [10]. The findings of some studies suggest that NMES might improve the cortical representation of swallowing function and might induce the recruitment of new cortical areas [11, 12]. In the pediatric population, there is a lack of studies describing the effects of therapy in relation to specific causes of dysphagia. There are also no clear guidelines regarding the execution of therapeutic procedures.

For this reason, we wanted to evaluate whether NMES – as a new treatment opportunity – is applicable and efficacious in the therapy of swallowing disorders in children with primary dysphagia. To answer this question, we compared the functional oral intake before and after the NMES therapy and looked for swallowing function changes in pediatric patients with primary dysphagia who received NMES swallowing therapy.

MATERIAL AND METHODS

DESIGN

A prospective study assessing swallowing function under NMES treatment due to primary dysphagia was designed and performed in the Department of Gastroenterology, Hepatology, Nutritional Disorders, and Pediatrics. Our department takes care of children with feeding problems from all over the country including those with dysphagia. Participation in the study was offered to caregivers of children who came to our outpatient clinic due to a lack of progress in the development of swallowing function.

All patients qualified for swallowing therapy were examined by a speech-language therapist specializing in dysphagia, a pediatric gastroenterologist, and a pediatric neurologist. A medical interview concerning neurological and developmental disturbances was performed, as were neurological examinations. In cases where active epilepsy or an oncological process of the central nervous system was suspected, electroencephalography or magnetic resonance imaging of the brain was performed. This was necessary because epilepsy and oncological diseases may be contraindications to performing NMES.

After medical evaluation, the final decision on participation in the study was made by the child's carers.

The procedure of the study involved admitting patients to the department of gastroenterology for 5-day stays for a cycle of therapy. The therapy was applied for 30 minutes twice a day for 5 consecutive days (a total of one hour of electrostimulation per day). This intense cycle was repeated every one or two months. The project assumed that each participant was entitled to complete 100 therapeutic sessions within a year (a total of 50 therapy days with 2 sessions each day).

We used the VitalStim Plus device (a new version with VMS and sEMG Triggered Stimulation, produced by Chattanooga in 2016). For the first session, we set the parameters accepted by the Food and Drug Administration (FDA) in 2002 as the VitalStim Protocol [13]. The pulse duration was 700 microseconds and the phase duration was 300 microseconds. During this session, we aimed to improve the blood supply to muscles and their endurance. The second session was focused on improving the elasticity and speed of reaction and was conducted using VMS Protocols with a phase duration of 100–300 microseconds – as

accepted by the FDA in 2016 [14]. We used only one frequency value for all therapeutic sessions – 80 Hz. In some cases, we used the trigger. We were unable to use the sEMG function for biofeedback exercises due to the poor cooperation of the patients.

The current that flows between electrodes first stimulates the sensory neurons in the skin. By increasing its intensity, we can reach deeper motor neurons with simultaneous contraction of the muscle fibers. Electrodes were placed on the skin surface of the face and the neck. The placement depended on the group of muscles to be stimulated. In total, 7 different electrode combinations were used [13]. The electrode arrangement used was different every day during the 5 days of the cycle and was adapted to the main problem identified by the speech therapist during the diagnosis [13]. For example, in one patient, we managed to determine that the main problem was the lack of laryngeal defenses, whereas in another, the issue was the limited mobility of the tongue. In such cases, the electrode arrangements used addressed the specific nature of the problem. The therapy was conducted by a speech therapist who is certified to perform VitalStim Therapy.

Based on the literature describing the effects of this therapy in adults, the best effects are obtained when NMES is associated with functional tasks [15, 16]. For this reason, some elements of conventional therapy such as oral feeding, chewing exercises, drinking from a cup or Kinesio Taping therapy were also performed during the NMES therapy or in between its cycles. This approach was used in cases where cooperation with the patient made it possible to maintain the effects of the therapy and involve parents in the process of observing changes. If possible, the children were fed orally during the NMES session. However, in most of our patients, only Kinesio Taping could be used as a therapy to support the first NMES cycle.

The therapeutic procedure did not involve performing a predetermined number of procedures. Instead, the number was determined taking into account:

- ending the therapy if the results satisfy the carers,
- not exceeding the limit of 10 cycles of therapy per child.

PARTICIPANTS

Participation in the study was offered to caregivers of children who came to our outpatient clinic due to a lack of spontaneous progress in the development of swallowing function, or the classical therapy provided at home was not effective, and feeding difficulties were not the result of behavioral feeding disorders or avoidant restrictive food intake disorders (ARFID). Eligibility also included an assessment of swallowing problems and ultimately patients presenting with the following symptoms of swallowing disorders were included in the study:

- no swallowing reflex response or a very poor response (only enteral feeding or needing frequent saliva suction),

- unsafe swallowing (aspiration into the lower respiratory tract or significant throat clearing problems),
- inefficient swallowing and age-inappropriate eating (diet inadequate for age and significantly prolonged duration of meals as a result of lack of motor skills for oral feeding).

Children who in the past had been fed orally without objections from their doctor or parents, but had lost this ability completely or partially as a result of their illness, were not eligible for the study because they did not meet the eligibility requirements for primary dysphagia.

According to previous arrangements, the therapy was terminated if its effects were already to the satisfaction of the caregivers or the caregivers themselves decided to end it, or the patient completed 10 therapy cycles (each consisting of five days repeated every 1–2 months).

OUTCOME MEASURES

Outcomes were personalized in terms of the main issue with swallowing. The evaluation was based on parents' and therapists' clinical observations as well as a videofluoroscopic swallow study (VFSS). Parents' observations were recorded by the therapist after each cycle of therapy and then confirmed by clinical observation of the patient. Parents were not focused on noticing predefined aspects of improvement. The therapist created a list of all observations, and then chose and named those that were common to several children and/or were repeated at different stages of the therapy, and/or occurred as persistent changes during the therapy. This is in line with qualitative research methodology.

We usually tried to conduct VFSS at the beginning of the therapy, as well as after about 2–5 cycles, and at the end of the therapy. We were unable to perform VFSS at the onset of the therapy in all patients because some of them did not display swallowing reactions at all and carrying out VFSS was unsafe. Over time, as their condition improved and their swallowing reactions were more pronounced, the test was performed. During the study, we used the penetration-aspiration scale [17]. Videofluoroscopic swallow study was used to assess the swallowing function on an ongoing basis and as a tool to help make decisions regarding the extension of oral feeding.

The overall therapy results were determined using the functional oral intake scale (FOIS) [18] with adjustments for use in children (Table 1) [19]. The therapist used FOIS to evaluate the patients before and after the NMES therapy. Higher FOIS scores show better feeding abilities.

STATISTICAL ANALYSIS

We compared the baseline against the final FOIS scale results. We used medians and quartiles to present the results as they were not normally distributed. The patients

TABLE 1. Functional oral intake scale

Level	Level description
1	Nothing by mouth
2	Tube dependent, with minimal attempts at liquid or food
3	Tube dependent, with consistent intake of liquid or food
4a	Total oral diet, but requiring special preparation of liquid (i.e., thickened liquids) +/- compensations (e.g., special feeding equipment, feeder uses special strategies)
4b	Total oral diet, but requiring special preparation of solid (e.g., liquid supplements or food of different texture than those required by peers) +/- compensations (e.g., special feeding equipment, feeder uses special strategies)
5	Total oral diet, without special preparation (i.e., regular thin fluids, foods of same texture as peers, no additional liquid supplements) but with compensations (e.g., special feeding equipment, feeder uses special strategies)
6	Total oral diet, with no restrictions relative to peers

TABLE 2. Characteristics of participants

Parameters	Total	Status of FOIS before therapy					
		FOIS 1	FOIS 2	FOIS 3	FOIS 4a	FOIS 4b	FOIS 5
Ages (years)							
< 1	10	9	1	–	–	–	–
1–3	11	5	2	–	2	–	2
3	13	7	2	1	1	–	2
Gender							
Male	18	8	4	1	1	–	4
Female	16	13	1	–	2	–	–
Primary disorders ^a							
Neurologic problem ^b	11	6	2	1	1	–	1
Genetic multiorgan disorders ^c	17	10	3	–	2	–	2
Anatomic problems ^d	6	5	–	–	–	–	1

^a It is difficult to precisely delineate the distinctions between categories of primary disorders because many genetic diseases also involve symptoms within the neurological system or structural abnormalities. Many structural disorders also co-occur with psychomotor developmental delays. Therefore, the selection of categories was based on predominant symptoms related to swallowing difficulties.

^b e.g. Moebius syndrome, cerebral palsy, muscular dystrophy, extreme prematurity, perinatal hypoxia

^c e.g. chromosomopathy, CHARGE syndrome, DiGeorge syndrome

^d e.g. condition after anastomosis of esophageal atresia (oro-pharyngeal dysphagia), Pierre-Robin syndrome, abnormalities in the larynx or palate area

FOIS – functional oral intake scale

TABLE 3. Number of patients participating in successive cycles of therapy

Number of cycles	1	2	3	4	5	6	7	8	9	10
Number of patients	34	28	17	14	7	5	5	4	3	2
Percentage of patients	100	82	50	40	20	15	15	12	8	5

were used as their own controls for comparison, which was justified by the fact that earlier therapy applied before the initiation of NMES had no effect. We used the Wilcoxon paired test to compare endline and baseline results using Statistica for Windows software (TIBCO Software Inc. 1984–2017).

RESULTS

We recruited 34 children with primary dysphagia caused by neurologic problems, genetic multiorgan disorders or anatomic problems. The mean age was 33 months (2 months to

7 years). Table 2 provides detailed information on this subject. All children suffered from primary dysphagia and none of them had ARFID or behavioral feeding disorders. During enrollment for the study, one patient was excluded due to symptoms of refractory epilepsy. Before starting NMES therapy, none of the patients showed symptoms of epilepsy. One patient discontinued therapy due to epilepsy, which manifested after the fourth cycle of treatment. None of our patients had a history of oncological issues.

Only 2 out of 34 patients completed the entire planned intervention (10 cycles). The average number of cycles was 3.5 ± 2.3 . Table 3 provides detailed information on

this subject. The reasons for early termination of participation in the study were either satisfactory therapy outcomes for the parents or the parents' decision to interrupt therapy due to the need for medical procedures in other departments or medical facilities, or discouragement due to the lack of rapid progress. In children with severe neurological deficits, complex problems, and requiring multidisciplinary medical care, which could explain the poor initial therapy outcomes, there was discouragement to continue therapy and ultimately the parents decided to withdraw from the study. Children who discontinued therapy after 1–2 cycles by parental decision had a low initial FOIS score (7 patients at FOIS level 1, 3 patients at FOIS 2, and 1 patient at FOIS 3).

Twenty-three out of 34 children participating in the study saw improvements in their oral feeding. Before training with NMES, 24 children were fed only by the enteral route, 7 were fed only orally, and 3 received partial enteral nutrition. After training, only 13 children were on total enteral nutrition, 12 were on exclusively oral nutrition, and 9 received partial enteral nutrition (Figure 1). In many cases, we did not see changes in the child's functioning at the onset of the therapy, i.e. after 1–2 cycles. Only after subsequent cycles, i.e., 3–4 months after starting the therapy, did changes begin to appear, making it possible to apply functional tasks and start oral feeding tests.

No improvement or further deterioration was noted in 11 out of 34 patients.

There was a significant improvement on the FOIS scale [1 (1; 2) vs. 2.5 (2; 6); baseline vs. final; median (lower; upper quartile); $p < 0.0001$]. The progress recorded on the FOIS scale was as follows: improvement by 1 level – 12 patients; by 2 levels – 5 patients; by 3 levels – 2 patients; by 4 levels – 1 patient; by 5 levels – 2 patients; by 6 levels – 1 patient. The greatest improvement, by 6 levels on the FOIS scale, was noted in 1 patient (Figure 2).

Additionally, we analyzed certain factors that can influence swallowing function, as reported by parents and checked by the therapist. We observed a positive change in the following aspects of swallowing function: effectiveness of defensive laryngeal reactions (15/34); control of saliva (9/34); reduction in gurgling breathing (9/34); enhancement of facial end tongue muscle tonus (12/34); coordination between swallowing and breathing (6/34); initiation or increased frequency of oral feeding (14/34) (Figure 3).

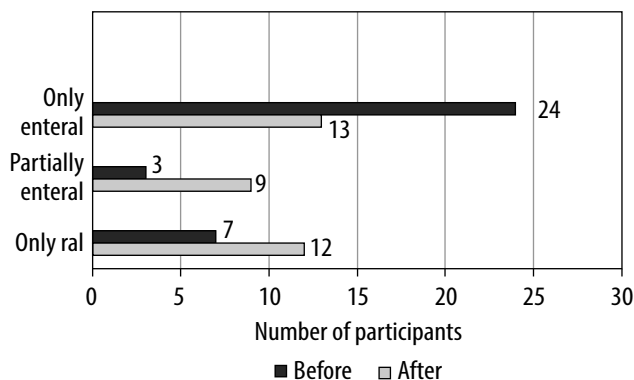


FIGURE 1. Method of feeding before and after neuromuscular electrical stimulation therapy

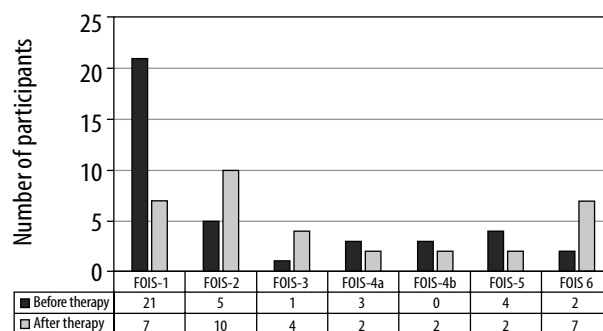


FIGURE 2. Progress in oral feeding after neuromuscular electrical stimulation therapy regarding functional oral intake scale score

improved facial and tongue muscle tonus (12/34); coordination between swallowing and breathing (6/34); initiation or increased frequency of oral feeding (14/34) (Figure 3).

DISCUSSION

In this prospective open study, we observed improvement in feeding and swallowing in neurologically impaired patients and children suffering from genetic multiorgan disorders or anatomical problems who received NMES treatment. We analyzed the variable components of swallowing since swallowing dysfunction results in various clinical problems in this group of patients. Our

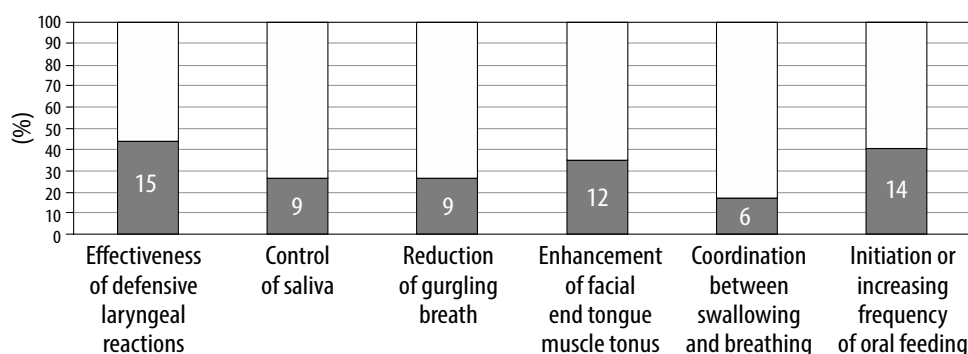


FIGURE 3. Improvement of swallowing factors reported by parents synthesized by speech language therapist ($N = 34$)

study significantly adds to recent reports on the efficacy of this therapy.

The description of the nature of the eating and swallowing process, neurological components, and the risk factors of oral eating impairments demonstrated how specific the intervention needs to be in primary dysphagia therapy. Rehabilitative interventions must include an exercise program that aims directly to improve the neuromuscular anatomy, physiology, or neural circuitry, thus directly influencing the biological underpinning of swallowing [20]. The literature regarding the use of electrostimulation in the treatment of pediatric dysphagia is currently limited and most of it describes non-randomized studies in small groups of patients [21]. Our study was designed to ascertain whether the treatment of swallowing disorders using NMES can be effective. It also helps to determine the elements that should be researched in greater detail in the field of dysphagia therapy according to the specific nature of swallowing disorders in children, such as the effectiveness of defensive laryngeal reactions, control of saliva, reduction in gurgling breathing, improved facial and tongue muscle tonus, coordination between swallowing and breathing, and initiation or increased frequency of oral feeding.

Unlike in pediatrics, NMES has been confirmed to be effective in the therapy of adults, which has been practiced for over 20 years, in numerous randomized trials and meta-analyses [22, 23]. However, therapies for children require a different approach. In the case of adult patients, we mainly deal with acquired dysphagia, while in children it is usually primary dysphagia. In children, oral feeding difficulties have a broader context, which is predominantly due to the lack of experience and the lack of understanding of feeding. This is particularly evident in severely neurologically impaired children with genetic syndromes and with severe intellectual disabilities. In such cases, the main difficulty in the field of therapy is cooperating with the patient.

In our opinion, NMES gives such opportunities. The placement of electrodes on the skin surface and adjusting the current parameters do not require the child to understand the situation, unlike in the case of traditional therapy and functional tasks. In our study, we noted an improvement in function, not only in patients with sufficient intellectual development to undertake functional tasks but also in those unable to do so. We assumed that the central organization of the food intake function is shaped by the child's development and is supported by the presence of a window of opportunity. It transforms from reflex reactions into volitional function. It is difficult to predict whether it will be possible to reach a motor level or sensitive level of stimulation before starting the therapy; however, it is worth emphasizing that NMES can also be effective at a sensitive level only [24, 25]. The superficial stimulation awakens the peripheral motor neurons, leading to stimulation of the brain at different levels. It

makes it possible to create a cortical representation and neural networks of swallowing function, which is crucial for patients with primary dysphagia.

Therefore, the goal of our therapy was to provide sensory and motor experiences from the peripheral stimulation to transfer activation to the upper structures of the nervous system. In our study, NMES therapy was spaced out over time, with 1–2-month breaks between intensive therapeutic cycles. In contrast, most previous studies were focused only on treatments lasting 1–3 months [21]. Our study was based on the theory that feeding function requires the creation of cortical representation for the functioning and development of the neural network, which we believe takes time and indicates that there may be no changes in swallowing function at the early stages of the therapy.

In our study, we found that 11 patients did not make progress in terms of oral feeding. The lack of progress in the therapy may also be related to the nature of the neurological damage and the degree of brain damage. The available literature does not provide evidence on how long NMES therapy should be continued and how often it should be repeated [26]. In our initial observations, we also did not record significant progress after 4 cycles in 3 children who were diagnosed with neuromuscular conduction disorders (congenital cranial dysinnervation disorders), which seems understandable considering that NMES is a therapy that relies on neuromuscular conduction.

The first study on the use of NMES in the treatment of pediatric dysphagia [2] proposed a breakdown of pediatric dysphagia into acquired and primary dysphagia. This study did not confirm whether NMES brings improvement in function in children with primary dysphagia. The negative results can be explained by the early termination of therapy (an average of 22 treatment sessions over 10 weeks), as well as the fact that the subjects were very heterogeneous in terms of age range, etiology, and pathophysiology of dysphagia.

Recent studies have shown the beneficial effects of NMES. In one of them, VFSS confirmed the positive effects of therapy in 5 children with cerebral palsy (CP) over the age of 5 [27]. Another study, also in a small group of patients (7 children under 2 years of age), confirmed the improvement of function in all patients. Intervention effects, as before, were assessed using VFSS [28]. Our team also used VFSS during the implementation of the study, though for us, it was a tool used to facilitate clinical decision-making rather than to define the final results of therapy. In a heterogeneous group of children with various swallowing problems, it is very difficult to establish a single method to assess the treatment effects that would apply to all study participants. That is why we focused on personalizing the impact of the therapy and measured various effects with FOIS [29].

One vital outcome of our study is the qualitative determination of factors that affect the improvement

of swallowing function. The relevant data were extracted from parents' reports and synthesized into dominant specific factors influencing swallowing improvement. The meaning of these factors was emphasized using the FOIS. No similar lists have been made before. Future studies aiming to assess the effectiveness of NMES swallowing therapy should consider not only the general scope of improvement of function but also its specific elements. The authors of a study that focused on improving biting function using NMES used a similar assumption as their basis. Unlike the previous studies, they used a control group and a large group of patients with CP. The experimental group saw such improvements as an increased volume of meals, reduced symptoms of salivation, increased range of tongue movements, and decreased symptoms of dysphagia [30].

In contrast to the therapy methodology presented in the previous studies, we used different methods of electrode application. In our patients, we applied 7 different electrode arrangements according to the specifics of the patient's swallowing problems recognized by the speech-language therapist. All above-mentioned studies used only one or at most two different electrode positions. It should also be noted that we used different therapy modes in our patients, i.e., not only FDA-approved parameters like the VitalStim Protocol but also a program that makes it possible to change the intensity and all other parameters. This is important because in patients with muscle diseases the frequency of the current can be decreased if signs of muscle fatigue are observed. In children with sensory hypersensitivity, on the other hand, it is possible to reduce phase duration, which makes the effect of the current less perceptible and the voltage can be increased to extend its reach to deeper muscles [13]. This functionality was enabled by the device we used.

The limitation of our study is the lack of a control group from a randomized trial. Apart from confirming the therapy's effectiveness, its advantages include a large group of patients, a list of factors that improve swallowing function, and a description of therapy methodology adapted to the specific problems arising from primary dysphagia. Further research should focus on investigating the impact of NMES on individual factors that build the function of swallowing and food intake in children, and it should consider homogeneous groups of patients. This approach should be compared to other standard procedures used in children suffering from primary dysphagia.

CONCLUSIONS

Evidence that NMES is effective in treating pediatric dysphagia remains weak. Our study should be seen as an attempt to find effective therapies for children who, due to their limitations and impairments, cannot participate in conventional therapy, adding to the limited data from pediatric studies. Neuromuscular electrical stimulation

in our study has shown promising results during therapy focused on the improvement of oral and swallowing function. Electrical stimulation improves functional oral intake and may increase the frequency of oral feeding and reduce enteral nutrition. It can be a chance for children who show limited cooperation or are unable to handle dietary modifications and undergo conventional oral motor training. Still, further controlled trials, focused on a more selected group of patients and possibly implementing methods developed and described in our study, are needed.

DISCLOSURES

1. The study protocol was approved by the Bioethics Committee. We obtained written informed consent for study participation from all parents of our patients. Patient clinical data were used anonymously. The children's caregivers were free to decide at any time to discontinue the therapy.
2. Assistance with the article: None.
3. Financial support and sponsorship: None.
4. Conflicts of interest: None.

REFERENCES

1. McSweeney ME, Jiang H, Deutsch AJ, Atmadja M, Lightdale JR. Long-term outcomes of infants and children undergoing percutaneous endoscopy gastrostomy tube placement. *J Pediatr Gastroenterol Nutr* 2013; 57: 663-667.
2. Christiaanse ME, Mabe B, Russell G, Simeone TL, Fortunato J, Rubin B. Neuromuscular electrical stimulation is no more effective than usual care for the treatment of primary dysphagia in children. *Pediatr Pulmonol* 2011; 46: 559-565.
3. Hadders-Algra M. The neuronal group selection theory: promising principles for understanding and treating developmental motor disorders. *Dev Med Child Neurol* 2000; 42: 707-715.
4. Arvedson JC. Evaluation of children with feeding and swallowing problems. *Lang Speech Hear Serv Sch* 2000; 31: 28-41.
5. Gisel E. Interventions and outcomes for children with dysphagia. *Dev Disabil Res Rev* 2008; 14: 165-173.
6. Hamdy S, Mikulis DJ, Crawley A, et al. Cortical activation during human volitional swallowing: an event-related fMRI study. *Am J Physiol* 1999; 277: G219-225.
7. Malandraki GA, Johnson S, Robbins J. Functional MRI of swallowing: from neurophysiology to neuroplasticity. *Head Neck* 2011; 33: S14-20.
8. Malandraki GA, Sutton BP, Perlman AL, Karampinos DC, Conway C. Neural activation of swallowing and swallowing-related tasks in healthy young adults: an attempt to separate the components of deglutition. *Hum Brain Mapp* 2009; 30: 3209-3226.
9. Gallas S, Marie JP, Leroi AM, Verin E. Sensory transcutaneous electrical stimulation improves post-stroke dysphagic patients. *Dysphagia* 2010; 25: 291-297.
10. Clark H, Lazarus C, Arvedson J, Schooling T, Frymark T. Evidence-based systematic review: effects of neuromuscular electrical stimulation on swallowing and neural activation. *Am J Speech Lang Pathol* 2009; 18: 361-375.
11. Oh BM, Kim DY, Paik NJ. Recovery of swallowing function is accompanied by the expansion of the cortical map. *Int J Neurosci* 2007; 117: 1215-1227.

12. Cugy E, Leroi AM, Kerouac-Laplanche J, et al. Effect of submental sensitive transcutaneous electrical stimulation on virtual lesions of the oropharyngeal cortex. *Ann Phys Rehabil Med* 2016; 59: 94-99.
13. Electrical stimulation & sEMG biofeedback in the treatment of dysphagia. Official manual of the international VitalStim Plus training course. DJO Publications 2016.
14. Available from: https://www.accessdata.fda.gov/cdrh_docs/pdf15/k153224.pdf, 30 (accessed: 12.2019).
15. Byeon H. Combined effects of NMES and mendelsohn maneuver on the swallowing function and swallowing-quality of life of patients with stroke-induced sub-acute swallowing disorders. *Bio-medicines* 2020; 8: 12.
16. Alamer A, Melese H, Nigussie F. Effectiveness of neuromuscular electrical stimulation on post-stroke dysphagia: a systematic review of randomized controlled trials. *Clin Interv Aging* 2020; 15: 1521-1531.
17. Rosenbek JC, Robbins JA, Roecker EB, Coyle JL, Wood JL. A penetration-aspiration scale. *Dysphagia* 1996; 11: 93-98.
18. Crary MA, Mann GDC, Groher ME. Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. *Arch Phys Med Rehabil* 2005; 86: 1516-1520.
19. Yi YG, Shin HI. Psychometrics of the functional oral intake scale for infants. *Front Pediatr* 2019; 7: 156.
20. Robbins J, Butler SG, Daniels SK, et al. Swallowing and dysphagia rehabilitation: translating principles of neural plasticity into clinically oriented evidence. *J Speech Lang Hear Res* 2008; 51: S276-300.
21. Propp R, Gill PJ, Marcus S, et al. Neuromuscular electrical stimulation for children with dysphagia: a systematic review. *BMJ Open* 2022; 12: e055124.
22. Carnaby-Mann GD, Crary MA. Examining the evidence on neuromuscular electrical stimulation for swallowing: a meta-analysis. *Arch Otolaryngol Head Neck Surg* 2007; 133: 564-571.
23. Burke D, Gorman E, Stokes D, Lennon O. An evaluation of neuromuscular electrical stimulation in critical care using the ICF framework: a systematic review and meta-analysis. *Clin Respir J* 2016; 10: 407-420.
24. Rofes L, Arreola V, López I, et al. Effect of surface sensory and motor electrical stimulation on chronic poststroke oropharyngeal dysfunction. *Neurogastroenterol Motil* 2013; 25: 888-e701.
25. Poorjavad M, Talebian Moghadam S, Nakhostin Ansari N, Daemi M. Surface electrical stimulation for treating swallowing disorders after stroke: a review of the stimulation intensity levels and the electrode placements. *Stroke Res Treat* 2014; 2014: 918057.
26. Sun Y, Chen X, Qiao J, et al. Effects of transcutaneous neuromuscular electrical stimulation on swallowing disorders: a systematic review and meta-analysis. *Am J Phys Med Rehabil* 2020; 99: 701-711.
27. Ma SR, Choi JB. Effect of electrical stimulation on aspiration in children with cerebral palsy and dysphagia. *J Phys Ther Sci* 2019; 31: 93-94.
28. Marcus S, Friedman JN, Lacombe-Duncan A, Mahant S. Neuromuscular electrical stimulation for treatment of dysphagia in infants and young children with neurological impairment: a prospective pilot study. *BMJ Paediatr Open* 2019; 3: e000382.
29. Andreoli SM, Wilson BL, Swanson C. Neuromuscular electrical stimulation improves feeding and aspiration status in medically complex children undergoing feeding therapy. *Int J Pediatr Otorhinolaryngol* 2019; 127: 109646.
30. Umay E, Gurcay E, Ozturk EA, Unlu Akyuz E. Is sensory-level electrical stimulation effective in cerebral palsy children with dysphagia? A randomized controlled clinical trial. *Acta Neurol Belg* 2020; 120: 1097-1105.