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Effects of Repetitive Magnetic Stimulation of the Vagus Nerve Combined with Intermittent Tube Feeding on Patients with Dysphagia Due to Cerebral Infarction

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Abstract: *Objective:* To study the effect of repetitive magnetic stimulation of the vagus nerve combined with intermittent tube feeding on the swallowing function and the incidence of aspiration pneumonia in patients with dysphagia due to cerebral infarction. *Methods:* This article recruited 60 patients after cerebral infarction as research subjects. The patients were divided into an observation group and a control group using the random number method. The control group received conventional rehabilitation treatment, and the observation group received repetitive vagus nerve magnetic stimulation combined with intermittent tube feeding on top of conventional treatment. The Gugging Swallowing Screen (GUSS) score, Rosenbek Penetration/Aspiration Scale (PAS) score, and Functional Oral Intake Scale (FOIS) score were measured before and after the test, and the occurrence of pneumonia in patients after treatment was recorded. *Results:* After treatment, the GUSS, PAS, and FOIS scores of the patients in the control group improved ($P < 0.05$), and the swallowing function improved; the incidence of aspiration pneumonia was 3.03%, which was lower than that in the control group ($P < 0.05$). *Conclusion:* Vagus nerve repetitive magnetic stimulation combined with intermittent tube feeding can well improve the swallowing function of patients after cerebral infarction.

Keywords: Intermittent tube feeding; Vagus nerve magnetic stimulation; Cerebral infarction; Swallowing disorder; Aspiration pneumonia

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1. Introduction

With the gradual application of mobile stroke units and the continued progress of late-time window reperfusion therapy, the survival rate of patients with cerebral infarction has significantly improved in recent years [1]. Swallowing disorder is one of the common complications after stroke, which is characterized by the inability to safely and effectively transport food from the mouth to the stomach. Studies show that 37% to 78% of patients will develop a swallowing disorder [2], resulting in pneumonia, malnutrition, and complications such as dehydration. Although current rehabilitation treatments can improve patients' ability to eat to some extent, a large number of patients still rely on dietary modification and enteral feeding. Long-term indwelling gastric tube may induce reflux esophagitis, bleeding, etc., affecting the recovery of the patient's swallowing function [3], and it is also highly predictive of mortality [4]. Therefore, it is of great significance to seek new strategies for the treatment of dysphagia after stroke to improve patients' quality of life and prognosis. In this study, the effect of repetitive magnetic stimulation of the vagus nerve combined with intermittent tube feeding on patients with dysphagia due to cerebral infarction was analyzed, and its treatment mechanism was explored.

2. General information and methods

2.1. Information

This study recruited 60 cerebral infarction patients in our department who met the inclusion and exclusion criteria and were randomly divided into an observation group and a control group. The purpose, nature, and potential risks of the trial were fully explained before the trial. All subjects expressed their willingness to comply with the research protocol and signed the informed consent form.

Inclusion criteria: (1) Patients who had the first onset of illness and whose head CT or MRI examination met the diagnostic criteria for cerebral infarction based on the proceedings of the 4th Meeting of the Chinese Medical Association on Cerebrovascular Disease; (2) patients with the age of onset of between 45 and 78 years old, with a course of disease of 1 to 6 years; (3) patients who were experiencing swallowing disorder for the first time; (4) patients who were stable and able to maintain a sitting position; (5) patients with swallowing abnormalities confirmed by swallowing angiography; (6) patients with no severe cognitive, visual, auditory dysfunction, or mental illness, with a mini-mental state examination (MMSE) score of ≥ 24 points.

Exclusion criteria: (1) History of dementia, or MMSE score < 22; (2) severe medical disease or disease progression, sleep apnea syndrome; (3) presence of cardiac pacemaker implantation, intracranial metal device, and metal internal fixation in the throat and neck; (4) severe anxiety, depression, schizophrenia, use of sedatives, and inability to cooperate with the treatment program; (5) swallowing disorders caused by other diseases.

2.2. Method

The subjects included in the control group received conventional rehabilitation treatment according to the "2017 Guidelines for Early Stroke Rehabilitation Treatment in China" [12] of the Neurology Branch of the Chinese Medical Association. The rehabilitation program is described as follows. (1) Orbicularis oris muscle training: lip contraction training, practicing whistling or blowing, ice stimulation, etc. (2) Throat exercises: soft palate training, vocal cord training, pharyngeal muscle training, laryngeal elevator muscle group training, Mendelsohn exercise, vocal training, etc. (3) Swallowing reflex training: cold stimulation, tongue control method, tongue massage, rapid soft palate arching, etc. (4) Ice stimulation: salivary side of the lips, anterior palatine arch, velum palatine, tonsil crura, etc. (5) Neuromuscular electrical stimulation treatment of the suprahyoid and inferior muscles.

The subjects included in the observation group received vagus nerve electrical stimulation combined with intermittent tube feeding at the same time on top of regular treatment. Wuhan YRD magnetic field stimulator, model YRDCCY-II was used to perform vagus nerve repetitive magnetic stimulation. Based on the position of the vagus nerve exiting the skull, we aimed at the jugular foramen in the patient's left mastoid area and performed stimulation in the sagittal direction along the direction of the vagus nerve.

Each session of the treatment lasted for 20 minutes (a total of 600 magnetic pulse stimulations), with a frequency of 5Hz, a stimulation time of 3s, and an interval of 27s. The stimulation intensity was adjusted between 1.5 and 6 Tesla based on the patient's mandibular movement. The treatment was done once a day, 5 days/week, and the course of treatment was 4 weeks. If the subject develops hoarseness, sore throat, cough, shortness of breath, or other adverse reactions, the treatment will be stopped. Intermittent tube feeding was performed before the operation, and the purpose of treatment and possible discomfort symptoms that may occur during the process were introduced to the patient in detail to eliminate their fear. Before each meal, patients were instructed to sit with their heads slightly raised, and a check was conducted to verify the absence of foreign objects in both the nasal and oral cavities. Once patency was confirmed, lubricant was applied to the feeding tube. Patients were then directed to open their mouths as the gastric tube was gently and slowly inserted through the mouth, alongside the patient's dysphagia, and advanced to the upper esophagus.

2.3. Evaluation methods and observation indicators

The indicators were evaluated by experienced therapists from the Rehabilitation Department of Huai'an People's Hospital at baseline and after 4 weeks of intervention. The assessors were blinded to the patient group assignments.

2.3.1. Gugging Swallowing Screen (GUSS)

GUSS includes direct and indirect swallowing test dimensions. If the patient could not swallow pasty food, it was indicative of severe dysphagia, elevating the risk of aspiration pneumonia, and was expressed as 0–9 points. If the patient could swallow pasty food but experienced difficulty with liquid and solid foods, leading to a potential risk of aspiration pneumonia, it was denoted as 10–14 points. When the patient could swallow pasty and liquid foods without coughing but struggled with solid food, signifying a low degree of dysphagia and a lower risk of aspiration pneumonia, it was scored as 15–19 points. A score of 20 indicated that the patient could swallow pasty, liquid, and solid food without dysphagia or with mild dysphagia, with a lower risk of aspiration pneumonia.

2.3.2. Rosenbek Penetration/Aspiration Scale (PAS)

The PAS scale is a swallowing function assessment scale based on swallowing imaging. This scale can not only quantify the severity of aspiration, but is more objectively reliable than other scales [5]. In this scale, penetration occurs when food falls into the vestibule of the larynx but remains above the vocal cords, while aspiration happens when food enters the trachea. Scale levels ranging from 1 to 8 correspond to 1 to 8 points, where the severity of the patient's swallowing function is inversely proportional to the score.

All patients underwent swallowing imaging examination within 24 hours of admission and upon completion of treatment, and PAS scores were calculated based on the images. Swallowing angiography was performed using digital subtraction angiography. In this procedure, the patient sat upright, and two frontal and lateral views were taken Xanthan gum (1.5g/bag by NUTRI, Japan) was added into 3 mL of Onapex (iohexol injection) to make thin (1.5%), medium thick (2.0%), and thick (3.0%) liquids, respectively. The patients were then instructed to swallow the liquids in the order of medium thick, thin, and thick [6]. The skull top, cervical esophagus, mandible, and cervical vertebrae could be observed within the fluoroscopy range.

2.3.3. Functional Oral Feeding Scale (FOIS)

The FOIS scale is a scale that analyzes and evaluates patients' oral feeding status. Scale levels 1 to 7 correspond to 1 to 7 points, and higher scores indicate better swallowing ability [7].

2.3.4. Incidence of aspiration pneumonia

The occurrence of aspiration pneumonia in both groups of patients was recorded.

2.4. Data statistics and analysis

Demographic and clinical data were statistically analyzed using SPSS 26.0. Measurement data were expressed as mean ± standard deviation. Paired samples *t*-test was to compare the data of both groups before and after treatment, and independent samples *t*-test was used for comparison between groups. The Wilcoxon Signed Ranks test was used for skewed distribution data, and the χ^2 test was used to compare the count data between groups, with a significance level of 0.05.

3. Results

3.1. Baseline characteristics

Table 1. Comparison of general information between the two groups of patients

Group	Number of cases	Male/female ratio	Age (years, mean ± standard deviation)	Disease duration (months, mean ± standard deviation)
Control group	30	19/11	66.23 ± 7.40	4.11 ± 1.01
Observation group	30	20/10	65.73 ± 7.56	3.95 ± 1.16
t/χ^2		0.07	-0.26	0.56
P		0.79*	$0.80^{\#}$	$0.58^{\#}$

Note: *The *P-value* of the χ^2-test; $^{\#}$the *P-value* of the independent sample *t*-test

3.2. Results of changes in swallowing function

Before treatment, there was no significant difference in the GUSS score, PAS score, and FOIS score between the two groups of patients ($P > 0.05$). Following treatment, the patients in the control group exhibited improvements in GUSS score, PAS score, and FOIS score compared to their scores before treatment ($P < 0.05$). Moreover, the patients in the observation group demonstrated notably higher GUSS score, PAS score, and FOIS score post-treatment in comparison to both their pre-treatment scores and the scores of the control group during the same period ($P < 0.01$, $P < 0.001$), as shown in **Table 2**.

Table 2. Comparison of GUSS, PAS, and FOIS scores between the two groups of patients before and after treatment (mean ± standard deviation)

Group	Number of cases		GUSS rating	PAS score	FOIS score
Control group	30	Before treatment	9.25 ± 1.06	4.8 ± 1.30	2.23 ± 1.14
		After treatment	11.84 ± 1.57*	3.27 ± 1.14*	3.83 ± 1.02*
Observation group	30	Before treatment	9.18 ± 1.01	4.80 ± 1.56	2.33 ± 1.37
		After treatment	$16.98 \pm 1.85^{*\#}$	$2.30 \pm 0.99^{*\#}$	$5.03 \pm 1.16^{*\#}$

Note: *$P < 0.05$ compared to before treatment; $^{\#}P < 0.01$ compared to the control group after treatment.

3.3. Incidence of aspiration pneumonia

Based on the results shown in **Table 3**, the incidence of aspiration pneumonia in the observation group was significantly lower than that in the control group ($P < 0.05$).

Table 3. Comparison of the occurrence of aspiration pneumonia in the two groups of patients (n, %)

Group	*n*	Number of occurrences	Incidence
Control group	30	7	22.33
Observation group	30	1	3.33
χ^2	–	–	5.192
P	–	–	0.023

4. Discussion

The pathophysiological mechanism underlying dysphagia after a stroke primarily involves nerve damage among the brain, tongue, pharynx, and their related structures. This damage subsequently results in reduced coordination among the muscles involved in swallowing [13]. The cerebral cortex, brainstem, and multiple pairs of cranial nerves, including the vagus nerve, play an extremely important role in the swallowing process. The vagus nerve is the longest pair of parasympathetic nerves in the human body. It is mainly responsible for regulating autonomic nervous functions such as heart rate, breathing, and digestion. Stimulating the sensory fibers of the vagus nerve can improve the patient's swallowing function. Studies have shown that the motor network of the undamaged area around the lesion as well as the symmetrical cortical and subcortical structures on the contralateral side after stroke shows significant reorganization. The plasticity of these areas provides an anatomical basis for functional recovery, while vagus nerve electrical stimulation can mediate motor synaptic reconnection and connection strengthening, which is key to the remodeling of neural function.

The occurrence of dysphagia is related to damage to the cortical motor area, sensory information feedback pathway, brainstem swallowing integration area, and other parts. Sensory impairment is also a potential cause of aspiration [14]. Peripheral swallowing information is continuously transmitted and fed back to the patient through sensory afferent pathways. Cortical centers that activate sensorimotor integration processes, which are essential for establishing safe and effective swallowing. In addition to controlling the movement of soft palate muscles, pharyngeal muscles, laryngeal muscles, and upper esophageal sphincter, the vagus nerve is also responsible for sensory uploading to the base of the tongue and the epiglottis area. Although after a stroke, the bihemispheric cortical symmetry pattern that integrates normal pharyngeal sensory input is disrupted, there is a temporal delay or impaired integration of sensory input to the hemisphere affected by the lesion, but it does not disappear.

Additionally, the vagus nerve has the ability to regulate neurotransmitters. Research shows that 80% of the vagus nerve are afferent fibers that terminate in the nucleus of the solitary tract of the brainstem. The fibers of the nucleus of the solitary tract project to the locus coeruleus and raphe nucleus, promoting the activation of 5-hydroxytryptamine, norepinephrine, and cholinergic. It is released throughout the cerebral cortex and strengthens synaptic connections in brain circuits; the joint activation of cholinergic and norepinephrine can also activate the anti-inflammatory mechanism and relieve brain inflammation [15].

Intermittent tube feeding simulates the movement of relevant oropharyngeal muscles during human food intake through repeated intubation, thereby stimulating muscle contraction of the tongue and pharynx and producing voluntary swallowing movements. Intermittent tube feeding includes intermittent oral to esophageal tube feeding, which is a new feeding compensation method that is inserted orally into the upper esophagus or stomach when the patient needs to eat and removed immediately after the feeding is completed. This method avoids negative effects of long-term tube feeding, such as gastric and esophageal mucosal damage and ulcers caused by indwelling gastric tubes, and damage to the absorption and utilization of nutrients.

The results of this study showed that all indicators of swallowing function in the observation group were significantly better than those in the control group, and the incidence of aspiration pneumonia was significantly lower than that in the control group. It is suggested that vagus nerve magnetic stimulation technology combined with intermittent tube feeding treatment for patients with dysphagia due to cerebral infarction can promote the improvement of swallowing function and reduce the risk of aspiration pneumonia. The combined application of the two can improve the treatment effect and accelerate the patient's recovery.

5. Conclusion

In summary, intermittent tube feeding combined with repetitive magnetic stimulation of the vagus nerve is effective in treating dysphagia in cerebral infarction. However, the treatment course of this study was short and its long-term efficacy could not be observed. Most of the indicators were based on the subjective feelings of the patients. Therefore, more objective indicators should be used in future research.

Disclosure statement

The authors declare no conflict of interest.

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