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ORIGINAL ARTICLE

Effect of Repetitive Transcranial Magnetic Stimulation on Post-stroke Dysphagia in Acute Stage

Fengjiao Zou[1] · Xiaoxu Chen[1] · Lingchuan Niu[1] · Yule Wang[1] · Jiaquan Chen[1] · Changqing Li[2] · Linyan Tong[2] · Jiani Li[2]

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Abstract

Repetitive transcranial magnetic stimulation (rTMS) play a important role for rehabilitation in stroke. But therapeutic schedule of rTMS in dysphagia after acute stroke is still controversial. The purpose of this study was to investigate the therapeutic effect of rTMS with different frequencies on dysphagia after acute stroke. From August 2019 to December 2020, 45 patients with post-stroke dysphagia were selected as research subjects, and randomly divided into 3 groups: the high frequency stimulation on bilateral hemisphere group (High group), bilateral high frequency stimulation on the affected hemisphere and low frequency stimulation on the unaffected hemisphere group (High-low group), and sham stimulation group (Sham group). On the basis of routine swallowing training (30 min) for all patients, the high group received 5 Hz rTMS in both hemispheres, the high- low group received 5 Hz rTMS in the unaffected hemisphere, 1 Hz rTMS in the affected hemisphere, and the sham stimulation group received sham stimulation in bilateral hemisphere. All participants were assessed with dysphagia handicap index (DHI), functional oral intake scale (FOIS) and videofluoroscopic swallowing study (VFSS) before the intervention (T1), immediately after intervention (T2) and 1 month after the intervention (T3). Meanwhile, according to the results of VFSS, Rosenbek penetration aspiration scale (PAS), the moving distance of hyoid bone towards the superior side (H), and pharyngeal response time (T) were analyzed and evaluated. After intervention, all three groups showed significant improvement in post-treatment scores from baseline ($P=0.000$). The results of DHI, PAS and H showed that the improvement in high group and high-low group was significantly greater than sham group ($P=0.000$). The results of FOIS and T showed that the improvement of bilateral high-frequency group was significantly greater than that of high-low group and sham group ($P=0.000$), and the difference lasted until 1 month after the end of treatment. Therefore, bilateral pharyngeal cortex high frequency rTMS and affected side high frequency/unaffected side low frequency rTMS can effectively improve swallowing disorder after acute stroke. However, the effect of bilateral high frequency rTMS is significantly higher than high-low in improving oral feeding function and pharyngeal response time.

Keywords Repetitive transcranial magnetic stimulation · Stroke · Dysphagia · Swallowing function

✉ Lingchuan Niu
niulingchuan@hospital.cqmu.edu.cn

Fengjiao Zou
zoufengjiao2018@163.com

Xiaoxu Chen
chenxx305@163.com

Yule Wang
381453903@qq.com

Jiaquan Chen
chenjiaquan@chenjiaquan.cn

Changqing Li
licq@cqmu.edu.cn

Linyan Tong
1026535931@qq.com

Jiani Li
623929204@qq.com

[1] Department of Rehabilitation, The Second Affiliated Hospital of Chongqing Medical University, Chongqing 400010, China

[2] Department of Neurology, The Second Affiliated Hospital of Chongqing Medical University, Chongqing 400010, China

Abbreviations

rTMS Repetitive transcranial magnetic stimulation
DHI Dysphagia handicap index
FOIS Functional oral intake scale
VFSS Videofluoroscopic swallowing study
PAS Rosenbek penetration aspiration scale

Introduction

Dysphagia is one of the common complications after stroke. According to the statistics of Rosemary, the incidence of dysphagia after stroke is as high as 51–55% [1–3]. Symptoms such as aspiration, choking, aspiration pneumonia and malnutrition caused by dysphagia, which seriously affect the quality of life of patients. At the same time, it also increases the medical burden of patients. Once stroke affects the brain areas related to swallowing, the symptoms that oral coordination disorder, impaired pharyngeal contraction, delayed laryngeal vestibule closure, and cricopharyngeus dysfunction may occur in clinical. When combined with cognitive dysfunction, the patients often show typical oropharyngeal dysphagia [4–6]. The traditional treatment of dysphagia is based on behaviour treatment and postural adjustments. In recent years, repetitive transcranial magnetic stimulation (rTMS), as a non-invasive and painless neuromodulation technique, has been introduced into clinical treatment of dysphagia [7–9]. The effect of rTMS on the M_1 region has been confirmed by some researchers, which can significantly improve the muscle strength of the affected limb, hand function and gait [10–12]. These results indicated that rTMS plays an important role in the repair of the damaged nerve function. Juan tried to stimulate the unaffected hemisphere with 1 Hz rTMS, and the results showed that the score of standardized swallowing assessment (SSA) of patients was significantly reduced. And Juan believed that low-frequency rTMS inhibited the unaffected hemisphere, which was a kind of relative excitatory effect to the affected side [13]. Bilateral hemispheres maintain functional balance through cross inhibition of corpus callosum under normal conditions. When the balance is broken after stroke, the unaffected hemisphere inhibit the excitability of the cortex of the affected through the corpus callosum to hindrance the recovery of motor function. Therefore, low frequency rTMS can inhibit the excitability of the unaffected cerebral hemisphere, which is to improve the excitability of the affected hemisphere [14, 15]. This "bilateral interhemisphhemisphal competitive inhibition pattern" is one of the widely recognized mechanisms by which TMS promotes neural function recovery. Eunhee found that 10 Hz rTMS can significantly reduce aspiration in dysphagia after acute stroke by stimulating the affected hemisphere [16]. This "compensatory mode" is another mechanism of rTMS considered by the industry at present. Di proposed another mechanisms of rTMS is the contralateral compensatory mode in 2014 [17]. It mainly refers to that functional compensation can only be carried out through the remaining areas around the lesion and the contralateral hemisphere in the case of severe cerebral hemisphere damage. The brain regions included M1 on the affected side, or the premotor cortex (PMC), supplementary motor area (SMA) on the contralateral side, or dorsal premotor cortex (PMd) on the contralateral side. Therefore, it's believe that high frequency rTMS on the remaining areas around the lesion and the contralateral hemisphere both are "compensatory mode". Later, Chun applied 5 Hz rTMS [18] to the affected hemisphere, but showed no significant difference between the trial group and the sham group. Then, some researchers put forward that whether it is high frequency on the affected hemisphere or low frequency on the unaffected hemisphere, it has limited effect on patients with severe neurological dysfunction [19, 20]. In order to further explore the effectiveness of rTMS parameters, researchers carried out clinical trials for different treatment modes, frequencies, intensities and sites. So we carried out this experiment, used different frequency of stimulation on bilateral brain regions, and compared the treatment results.

Materials and Methods

Participants

From August 2019 to December 2020, 45 patients with dysphagia after stroke treated in the Rehabilitation Department of the Second Affiliated Hospital of Chongqing Medical University were studied. All patients were selected according to the following inclusion criteria: ① All patients had cerebral infarction confirmed by head computed tomography or magnetic resonance imaging; ② All patients had the first onset, within 1 week to 1 month after onset; ③ Age: 40–70 years; ④The Kubota Water Test score ≥ 3; ⑤5 ˃ Modified rankin scale (MRS) ≥ 3; ⑥ Patient that can tolerate rTMS, complete treatment, and cooperate to complete the judgment of various scales. Exclusion criteria: ① Patients with contraindications to TMS; ② Severe consciousness and cognitive impairment, unable to cooperate with treatment; ③ Brainstem injury; ④ Other serious organic diseases or unstable vital signs; ⑤ A history of esophageal diseases, pharyngeal local lesions, pharyngeal neoplasm and pharyngeal structural diseases [19].

The SPSS 26.0 was used for the process of minimization to evenly distribute patients of different age and stroke severity. 45 patients were randomly divided into three groups: the bilateral high frequency stimulation on bilateral hemisphere group (High group), high frequency stimulation on the affected hemisphere and low frequency stimulation on the unaffected hemisphere group (High-low group), and sham stimulation on bilateral hemisphere group (Sham group). All patient signed informed conset forms with the consent of patients and their families in this study. When the patient is unwilling to continue treatment, or the patient has aggravation, epilepsy and other conditions during treatment, the patients who need to interrupt treatment are regarded as abscission cases. At the same time, the patients who cannot complete the follow-up evaluation are also regarded as abscission cases.

One patient in the sham stimulation group dropped out due to gastrointestinal bleeding. One patient in the high group and one in the sham stimulation group refused to undergo the third videofluoroscopic swallowing study (VFSS) evaluation because they consciously recovered in good condition. Therefore, a total of 42 patients completed the study (Fig. 1).

Experimental Design

This study was a double-blind randomized controlled design. All participants were randomly divided into three groups by SPSS 26.0: high group, high-low group, and sham group. None of the participants knew their group. All patients were assessed by two therapists who was not involved in treatment and knew nothing about group. In rTMS, patients were treated in batches, unaware of each other. This study was reviewed and approved by the medical ethics committee of the Second Affiliated Hospital of Chongqing Medical University, and the clinical trial registration number is chictr1900026712.

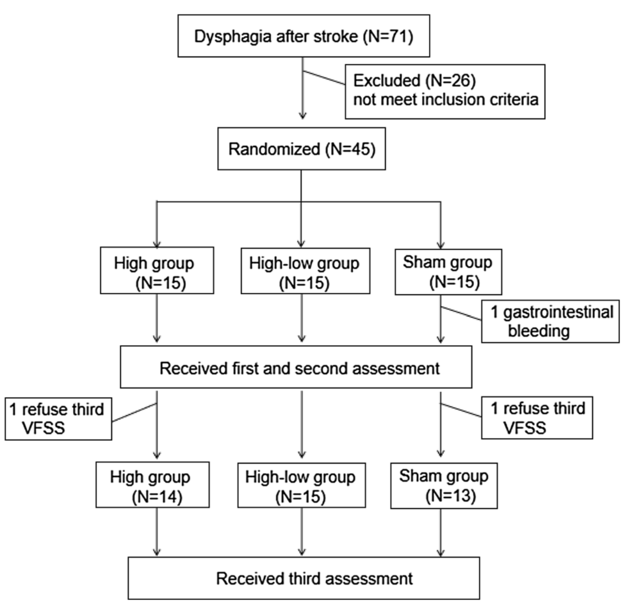

Fig.1 Flowchart

During the 4-week treatment period, all patients received rTMS for 5 consecutive days per week and a total of 20 times of treatment. Within 30 min of the completion of rTMS, participants received 30 min of routine dysphagia therapy, such as protecting airway maneuver, sensory stimulation, oral motor exercises and so on.

Repetitive Transcranial Magnetic Stimulation Application (rTMS)

Patient was instructed to sit in the chair or take a comfortable supine position, and avoided moving head as far as possible during the treatment. rTMS was using the M100 transcranial magnetic stimulation therapy instrument produced by Shenzhen Yingzhi Technology Company. After locating the unaffected pharyngeal motor cortex, we regard the mirror area of the affected area as another stimulation point. In the high group, operator first placed the 75 mm “figure 8” coil in the pharyngeal motor cortex of the unaffected hemisphere and stimulated with 5 Hz and 90% RMT. After that, place it at the same part of the affected side and treat it in the same way, with 600 pulses on the left and right respectively. In high-low group, the affected hemisphere received 5 Hz and 90%RMT, after that the unaffected hemisphere received 1 Hz with 120%RMT. Also, 600 pulses on each side. In sham stimulation group, use the same parameters as the high group, operator placed the coil 90° perpendicular to the scalp. The rTMS protocols used in this study were based on the safety guidelines for rTMS applications [21].

Determination of the Resting Motor Threshold (RMT)

Each patient were instructed to sit in a chair and record unaffected pharyngeal electromyography (EMG) data by a 3.2 mm diameter intraluminal catheter (Gaeltec Ltd, Isle of Skye), with a built-in pair of bipolar platinum ring electrodes. The EMG activity was amplified using the Medelec Synergy EMG/EP system (Medelec, Oxford, UK) and the data were band-pass fifiltered at 10–2000 kHz. After the vertex of skull was determined, moved the figure 8 coil from the vertex to 2–4 cm anteriorly and 4–6 cm laterally. Single-pulse TMS with 80% of the maximal stimulator output was used and the EMG was recorded. The site of the maximal motor evoked potential (MEP) was regard as pharyngeal motor cortex.

After the pharyngeal motor cortex was determined, the resting motion threshold of cortical excitability was further tested. We placed single-pulse TMS on the unaffected lateral pharyngeal motor cortexand observed MEP and adjust the intensity at the same time. The minimum stimulation intensity when the MEP by at least 3 of the 5 stimuli is > 50 uV is set as the resting motor threshold [22].

Swallowing Function Assessments

To assess the severity of dysphagia in detail, the dysphagia handicap index (DHI), functional oral intake scale (FOIS) and videofluoroscopic swallowing study (VFSS) were used. Each participant was assessed three times: before the intervention (T1), immediately after intervention (T2) and 1 month after the intervention (T3). DHI is a scale that has been confirmed as an effective and accurate evaluation for the dysphagia. It includes three aspects: physiology, function and emotion. There are 25 scoring items in total. Each item is scored from 1 to 4 according to the severity of the patient, and the full score is 100. The higher scores indicating the more severity of dysphagia [23]. FOIS is a 7-point scale that is widely applied to evaluate the diet function in dysphagia. Level 1 represents nonoral feeding at all and level 7 represents complete oral feeding without restrictions [24].

Videofluoroscopic Swallowing Study

Each participant kept in sitting and focusing on the marker in front of them at eye level to keep head position. All patients was given 3, 5,and 10 ml of thick fluid which was mixed with $BaSO_4$ contrast agent (Qingdao Hongdie New Material Co., LTD) and thickener (Nestle Hongkong., LTD), prepared by the therapist in advance. And each volume performed three trials. A coin with a diameter of 19 mm was affixed to the mandible of the patient as a measuring tool for length comparison. VFSS records the entire swallowing process in real time at 24 frames per second. The coordinate system is established by take the line connecting the anterior inferior margin of C2 and to the C4 as Y-axis, and the straight line that is perpendicular to the Y-axis and passes through the anterior inferior margin of C4 as the X-axis. The anterior superior margin of the hyoid bone was used as the observation point, and the Y-value of the point at the beginning of hyoid bone movement and the highest point was recorded (Fig. 2). The absolute value of the difference between the two Y values is the maximum vertical travel distance of the hyoid bone, is recorded as H (the average value of three meals). The H is the lifting amplitude of hyoid bone towards the superior side. During the process, the pharyngeal response time was observed. The images of the proximal part of the food bolus reach the final region of the hard palate and the the beginning of hyoid bone movement [25], of which the time interval between the two images was calculated and recorded as T (the average value of three meals).

Meanwhile, Rosenbek penetration aspiration scale (PAS) was scored based on VFSS. The PAS scores for varying degrees of aspiration from the mouth to the esophagus. The scale is divided into 8 levels. Grade 1: contrast does not enter airway. Grade 2: Contrast enters airway, remains above vocal folds, no residue. Grade 3: Contrast remains above vocal folds, visible residue remains. Grade 4: Contrast contacts vocal folds, no residue. Grade 5: Contrast contacts vocal folds, visible residue remains. Grade 6: Contrast passes through glottis, no subglottic residue visible. Grade 7: Contrast passes through glottis, visible subglottic residue despite patient response. Grade 8: Contrast passes through glottis, visible subglottic residue, no patient response. Grade 1 is normal, grade 2 to 5 is penetration, grade 6 to 8 is aspiration, and grade 8 is recessive aspiration. The higher grade means the more serious aspiration [26]. The scale can effectively evaluate the degree of aspiration.

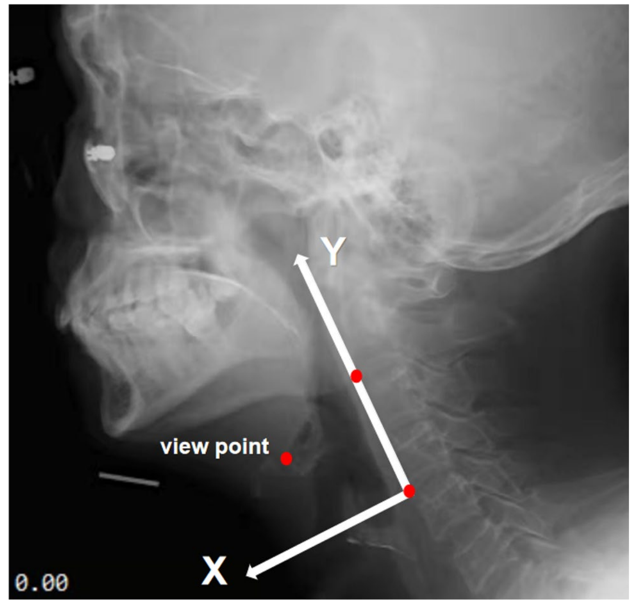

Fig. 2 The measurement of the moving distance of hyoid bone towards the superior side

Statistical Analyses

All data analysis in this experiment was carried out using SPSS 26.0. In order to evaluate interaction effects between intervention and time, time was the main internal factor and grouping was the main inter body factor, and repeated measurement analysis of variance (ANOVA) was carried out. The minimal difference test was used in analyzing differences between groups after intervention. We performed chi-squared test in assessing sex, type of stroke and lesion. For observing the differences in raw scores, define the change from baseline to each time point as ‘change value (Δ)’and compare the between-group differences in the baseline and each point by one-way ANOVA. $P < 0.05$ was regarded as significant and P value < 0.01 was adjusted for multiple comparisons. Nonparametric statistics were performed with Kruskal–Wallis test.

Results

A total of 42 participants completed the study. There were no significant differences in gender, age, course of stroke, type of stroke, evaluation score of overall condition (MRS) and lesion distribution among the three groups. According the evaluation of swallowing function, no significant in DHI, FOIS, PAS and H and T at baseline (Table 1).

All H, T, DHI, FOIS and PAS values have significantly improved over time ($P<0.05$). There were significant interaction between time and intervention in FOIS ($F_{2,41}=36.678$, $P<0.05$), PAS ($F_{2,41}=19.733$, $P<0.05$), and T ($F_{2,41}=12.200$, $P<0.05$).

All dates were compared at each time point, DHI, FOIS, PAS, H, and T values were significantly improved from baseline in high group, high-low group and sham group. The results of DHI showed that the high group and the high-low group was significantly improved than sham group ($F_{2,41}=14.053$, $P=0.000$). The high group and high-low group showed a significantly improvement in PAS than sham group ($F_{2,41}=45.758$, $P=0.000$) (Fig. 3). In the results of FOIS, high group has a significantly change than high-low group and sham group ($P=0.000$), and the improvement persisted until 1 month after treatment ($P=0.000$) (Fig. 4). According to H, high group and high- low group had significantly higher than sham stimulation group ($F_{2,41}=12.339$, $P=0.000$). The results of T showed that the change in the high group was significantly larger than high-low group and sham group ($F_{2,41}=400.332$, $P=0.000$) (Fig. 5).

Discussion

The purpose of this study was to investigate the effect of different frequencies rTMS in bilateral hemisphere on dysphagia after acute stroke. The results showed that both high frequency and low frequency rTMS could effectively improve dysphagia after acute stroke. But high frequency rTMS in bilateral hemisphere has significantly improvement than the low in improving patients' oral feeding function and the pharyngeal response time.

In this trial, the FOIS value of bilateral high-frequency rTMS group increased to 6.73, increased by 4.86 compared with that before treatment, which was significantly higher than 3.54 and 2.14 of the other two treatment methods. The results showed that feeding function status was significantly improved in bilateral high-frequency rTMS group. After intervention, it was found that the patients of bilateral high-frequency rTMS group were more likely to meet their nutritional needs through oral feeding and had higher acceptance about different viscosity of food than the other two groups. In previous studies, Ryo Momosaki also used used high-frequency rTMS to stimulate the bilateral hemispheres of patients with post-stroke dysphagia. It was found that the FOIS improved slightly [27], which is different from the results of this study. However, there were only 4 participants in Ryo momosaki's study, so it is considered that it can not accurately represent the improvement of oral feeding function. Similarly, Tarameshlu performed high-frequency TMS on the unaffected hemisphere of 18 patients with post-stroke dysphagia and found significant improvement in feeding efficiency and FOIS scores after treatment [28], which is similar to our findings.

Table 1 Epidemiology and swallowing function at baseline

Variables	High ($N=15$)	High and low ($N=15$)	Sham ($N=15$)	P
Sex	6:9	6:9	10:5	0.241
Age	59.33 (6.85)	58.93 (7.53)	60.07 (5.40)	0.894
Duration after stroke (days)	20.07 (5.06)	21.47 (5.55)	20.13 (5.68)	0.731
Lesion site (left:right)	7:8	8:7	6:9	0.765
Stroke type (ischemic:hemorrhagic)	9:6	10:5	10:5	0.908
MRS	3.60 (0.51)	3.47 (0.52)	3.40 (0.51)	0.555
Water swallow test	4.33 (0.72)	4.20 (0.68)	4.33 (0.72)	0.838
DHI	62.33 (9.15)	62.60 (9.64)	63.36 (8.55)	0.958
FOIS	1.87 (1.06)	1.73 (0.59)	2.00 (0.78)	0.803
H	11.93 (1.83)	11.81 (1.44)	11.23 (2.12)	0.935
T	3.54 (0.55)	3.60 (0.81)	3.83 (0.67)	0.708

Mean (standard deviation)

MRS Modified Rankin Scale, *DHI* Dysphagia Handicap Index, *FOIS* Functional Oral Intake Scale, *H* the lifting amplitude of hyoid bone towards the superior side, *T* pharyngeal response time

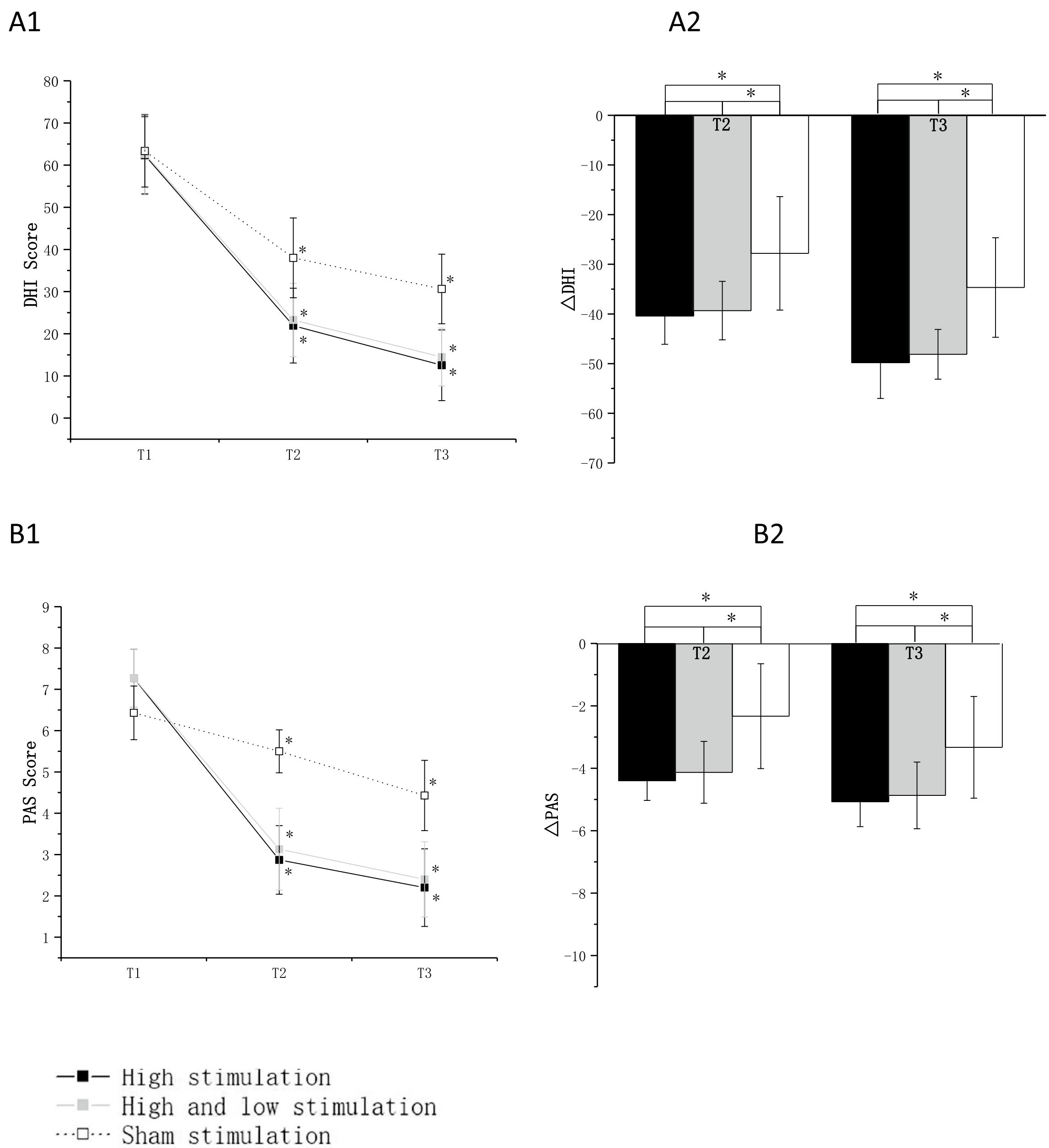

Fig. 3 Swallowing function assessment: **A1** score of dysphagia handicap index (DHI), **A2** change in DHI contract with baseline, **B1** score of Rosenbek penetration aspiration scale (PAS), **B2** change in PAS contract with baseline.Error bars represent the standard deviation for each condition. (*) represent a significant difference (*$P<0.05$): the full black line and box represent high group, the full gray line and box represent high-low group, and the dashed line and full white box represent sham group. T1: baseline before the intervention; T2: immediately after the intervention; T3: 1 month after cessation of the intervention

Patients with dysphagia often suffer from the interference of psychological factors, because of early severe coughing and obstruction, have fear of feeding and thus affect the quality of life [29, 30]. In this trial, use DHI to assess psychological state of patients, which better reflects how patients really feel about their own recovery process. It was found that DHI improved in all patients from baseline. Patients in high group and high-low group showed significant improvements in the third part of the emotion in particular. Individual patients in the sham group showed significant improvement in DHI scores, although there was no significant change in functional part after treatment. That possibly affected by psychological of the patient. Most researchers focused on the improvement of function but neglected the psychological

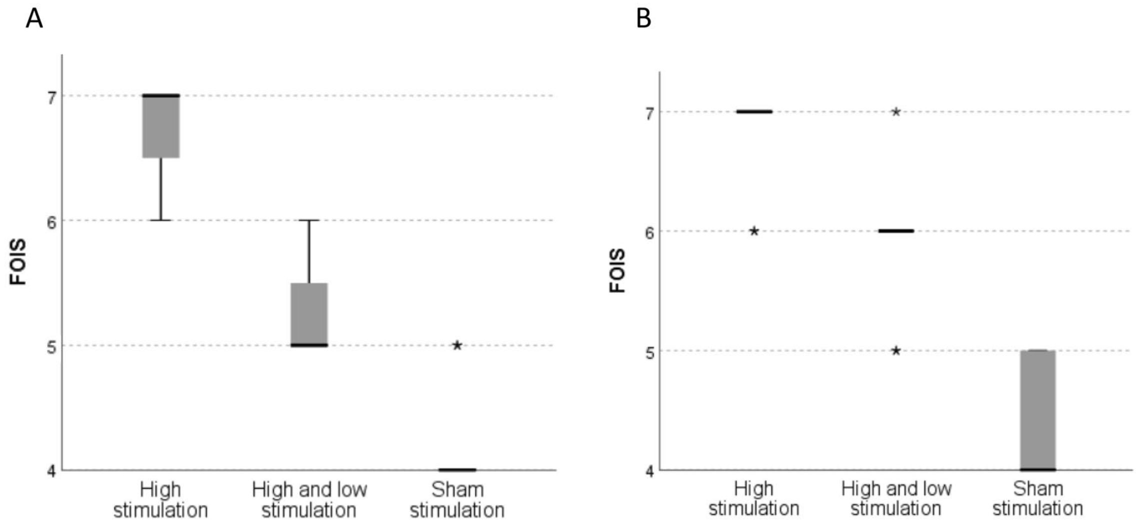

Fig. 4 The degree of functional oral intake scale (FOIS): **A** immediately after the intervention; **B** 1 month after cessation of the intervention. (⋆) represent extreme values, only 1 or 2 cases

changes of patient in previous studies [31–33]. In this study, psychological factors were taken as one of the evaluation items to better reflect the impact of improvement in swallowing function about quality of life.

According to the VFSS, the PAS values of bilateral high-frequency rTMS group and high-low group decreased by 4.4 and 4.14 compared with those before treatment, which was significantly higher than that of the sham group by 0.93 ($P < 0.05$). VFSS showed that the laryngeal movement of patients in the high group and the high-low group was also greatly improved. At the same time, both feeding time, the delay of pharyngeal transmitting, and the feed efficiency were improved. For safety reasons, only use thick liquid instead of water in the VFSS in this study, which may result in a high PAS score. During this process, it was also found that patients who received rTMS had significantly reduced pharyngeal residues, but more accurate evaluation is needed. This is also where we need to improve in the next trial for more comprehensive evaluation and analysis.

In the evaluation results, there was no significant difference in H between the high group and high-low group. Gary investigated whether VFSS test results could effectively reflect the function of dysphagia, and the result showed that pharyngeal response time and hyoid lifting amplitude were one of the biomechanical factors that could effectively reflect the function of larynx in thick liquid [34]. Laryngeal lifting is essential for airway protection during pharyngeal swallowing. Pathologically reduced and delayed of laryngeal lift is the most common cause of aspiration. Similarly, Ian showed that when pharyngeal response time is shortened, the circopharyngeus will open earlier, thus increase swallowing efficiency [35]. Therefore, evaluated pharyngeal response time and hyoid lifting amplitude in this study can better judge the improvement of feeding efficiency. It was believed that the effects of bilateral high frequency rTMS on improving the movement of the laryngeal complex were similar to that high-frequency on the affected side and low-frequency on the unaffected in this trial. In previous trials, after the researchers used 1 Hz low-frequency TMS to stimulate the unaffected hemisphere, the aspiration of patient was significantly improved, which is consistent with our results. After analyzing cortical excitability, it was found that although the unaffected cortex received stimulation, the nerve excitability of the affected cortex was also significantly improved [13]. This indicates that the excitability between the unaffected hemisphere and the can influence each other, which is also the reason why the swallowing function in the high-low group was also significantly improved in the results of this experiment.

In this study, we stimulated the bilateral pharyngeal motor cortex, and the results showed that stimulation of this region significantly improved the feeding function and feeding efficiency to enhance swallowing behavior. Which is similar to the results of Samantha that stimulation of pharyngeal motor cortex can enhance sensory input of cortex to enhance pharyngeal sensation effectively, improve pharyngeal reaction time and enhance swallowing behavior [36].

Hamdy's research showed that the excitability of the pharyngeal motor cortex of the unaffected cerebral hemisphere was significantly increased in patients without dysphagia after stroke and in patients with dysphagia but recovery [37], indicating that improving excitability of the unaffected hemisphere is the key of swallowing functional recovery. And it was found that high frequency rTMS on unaffected hemisphere has more advantages than low frequency in our trial. Wu proposed that the mechanism of

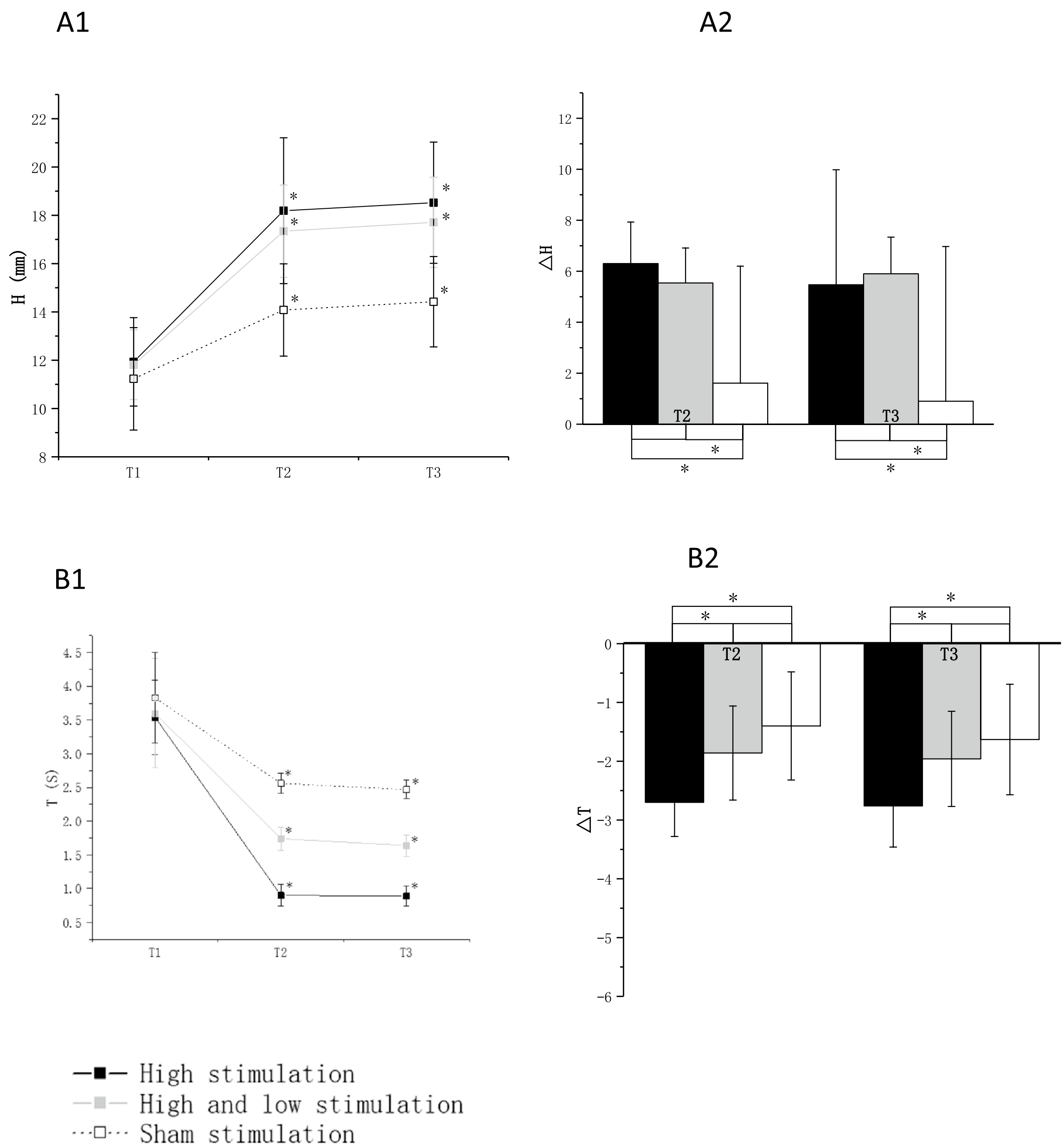

Fig. 5 Swallowing function assessment based on VFSS: **A1** the lifting amplitude of hyoid bone towards the superior side(H), **A2** change in H contract with baseline. **B1** The pharyngeal response time(T), **B2** change in T contract with baseline. Error bars represent the standard deviation for each condition. (*) represent a significant difference (*$P<0.05$): the full black line and box represent high group, the full gray line and box represent high-low group, and the dashed line and full white box represent sham group. T1: baseline before the intervention; T2: immediately after the intervention; T3: 1 month after cessation of the intervention

rTMS is related to gamma-amminobutyric acid (GABA) mediated intracortical inhibition. High frequency rTMS can increase the excitability of cerebral cortex for a long time [38], which may be because high frequency rTMS reduces the excitability of GABA conduction inhibitory areas in pharyngeal motor cortex, thus promoting GABA conduction and enhancing cortical excitability. Not only were the regions of the cortex activated, but also the distal subcortical regions were activated.

In this experiment, high-frequency had better result in feeding and pharyngeal reaction time than the low. In the acute stage, we think that the excitability of the whole cerebral cortex is decreased, and the decrease of the affected side is more obvious. Then, low frequency has a limited effect on the improvement of contralateral cortical excitability, while bilateral high frequency can improve the excitability of the whole cortex. That is more beneficial to the recovery of nerve injury. Therefore, high-frequency had better result. And our study showed that DHI, PAS, FOIS, H and T of high group and high-low group were still significantly better than sham group at T3. So we think that the effect of rTMS is sustainable and rTMS has a significant effect on the subsequent improvement of dysphagia.

The main purpose of this study was to compare the therapeutic effects of rTMS with different frequencies. There is no control group was set for treatment time. We suspect that the longer the treatment, the more significant effect will be to some extent. But it is likely that the improvement will not significantly beyond the most suitable treatment time. That will be compared in subsequent experiments.

In general, many reviews and meta-analyses have confirmed the efficacy of rTMS in stroke [39–41]. There are those that favor high frequency, and there are those that favor low frequency. Based on the results of this test, we believe that high frequency may be more effective in the acute phase, mainly in swallowing behavior. It may be that different stimulation frequency have different therapeutic effects in different periods of stroke.

In any case, although the mechanism by which high-frequency ameliorates dysphagia after stroke remains to be further explored, its results on the improvement of swallowing function are convincing, which will set a foundation for our future clinical treatment.

Conclusions

rTMS acting on the pharyngeal cortex of bilateral brain regions can effectively improve the swallowing disorder after acute stroke. Bilateral high frequency rTMS is significantly better than high-affected low-unaffected in improving oral eating function and swallowing initiation time.

Limitation

The sample in this study was just 15 in each group, and the follow-up time was only 1 month, so the evaluation content needs to be more comprehensive and accurate. Also, extremely serious cases were excluded, which will be further researched in our future studies.

Author Contributions LN conceived of the study, and participated in its design and manuscript preparation. FZ and XC participated in manuscript preparation and dysphagia therapy. JC and JL participated in data collection and statistical analysis. CL and LT participated in swallowing function assessments. YW participated in rTMS treatment. All authors read and approved the final manuscript.

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Declarations

Competing Interests The authors declare that they have no competing interests.

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