Intermittent Theta Burst Stimulation Combined with Jaw Resistance Training for Dysphagia in Stroke Patients: A Randomized Controlled Trial Post-Print

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Abstract

Background Dysphagia is a common complication after stroke, and recovery of swallowing function is of great significance for patients' nutrient intake, reduction of complications, and improvement of quality of life. Although intermittent theta burst stimulation (iTBS) and chin tuck against resistance (CTAR) training have been proven to have significant efficacy in improving dysphagia, there are currently few studies on the combined use of iTBS and CTAR for treating post-stroke dysphagia patients, and its rehabilitation efficacy needs further verification. Objective To observe the clinical efficacy of iTBS combined with CTAR on swallowing function in stroke patients. Methods From March 2023 to July 2024, 90 patients with post-stroke dysphagia who visited the Department of Rehabilitation Medicine at the First Affiliated Hospital of Bengbu Medical University were selected. Patients were divided into a conventional group (n=30), a CTAR group (n=30), and a combined group (n=30) using the random number table method. The conventional group received conventional swallowing training, the CTAR group received CTAR in addition to the conventional training, and the combined group received cortical iTBS stimulation in addition to CTAR, 5 times per week for 4 weeks. Before and after treatment, the Standardized Swallowing Assessment (SSA) and Functional Oral Intake Scale (FOIS) were used for evaluation. Surface electromyography (sEMG) was used to measure the swallowing duration and maximum peak amplitude of the suprahyoid muscle group, and the clinical efficacy of the three groups was compared. Results Ultimately, 30 cases were included in the conventional group, 30 in the CTAR group, and 30 in the combined group. After 4 weeks of treatment, the SSA scores of patients in all three groups decreased compared with before treatment, while the FOIS scores and maximum peak amplitude of sEMG in-

creased, and the swallowing duration shortened compared with before treatment (P<0.05). After 4 weeks of treatment, the SSA scores of patients in the CTAR and combined groups were lower than those in the conventional group, while their FOIS scores and maximum peak amplitude of sEMG were higher, and their swallowing duration was shorter (P<0.05); the SSA scores of patients in the combined group were lower than those in the CTAR group, while their FOIS scores and maximum peak amplitude of sEMG were higher, and their swallowing duration was shorter (P<0.05); and the overall effective rate of the CTAR and combined groups was higher than that of the conventional group (P<0.05), with the combined group's overall effective rate being higher than that of the CTAR group (P<0.05). Conclusion iTBS combined with CTAR can effectively improve swallowing function, strengthen swallowing muscle strength, and enhance the quality of life in patients with post-stroke dysphagia.

Full Text

Intermittent Theta Burst Stimulation Combined with Chin Tuck Against Resistance Training for Dysphagia in Stroke Patients: A Randomized Controlled Trial

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Abstract

Background: Dysphagia is a common complication following stroke, and recovery of swallowing function is crucial for patients' nutritional intake, complication reduction, and quality of life improvement. Although intermittent theta burst stimulation (iTBS) and chin tuck against resistance (CTAR) have demonstrated significant efficacy in improving dysphagia, few studies have investigated the combination of iTBS with CTAR for post-stroke dysphagia, and its rehabilitative effects require further validation. **Objective:** To observe the clinical efficacy of iTBS combined with CTAR on swallowing function in stroke patients. **Methods:** From March 2023 to July 2024, 90 patients with post-stroke dysphagia treated at the Department of Rehabilitation Medicine of The First Affiliated Hospital of Bengbu Medical University were enrolled and randomly divided into three groups using a random number table: conventional group (n=30), CTAR group (n=30), and combined group (n=30). The conventional group received standard swallowing training, the CTAR group received CTAR in addition to conventional training, and the combined group received iTBS

cortical stimulation in addition to CTAR. All treatments were administered five times per week for four weeks. The Standardized Swallowing Assessment (SSA) and Functional Oral Intake Scale (FOIS) were used for evaluation before and after treatment. Surface electromyography (sEMG) was used to measure swallowing duration and maximum amplitude of the suprahyoid muscle group, and clinical efficacy was compared among the three groups. **Results:** All 90 patients were included in the final analysis (30 per group). After four weeks of treatment, SSA scores decreased significantly in all three groups compared with baseline ($P<0.05$), while FOIS scores and sEMG maximum amplitude values increased significantly, and swallowing duration decreased significantly ($P<0.05$). Post-treatment comparisons revealed that both the CTAR and combined groups had lower SSA scores, higher FOIS scores and sEMG maximum amplitudes, and shorter swallowing durations than the conventional group ($P<0.05$). The combined group showed even greater improvements than the CTAR group across all measures ($P<0.05$). Additionally, the overall effective rates were higher in the CTAR and combined groups compared with the conventional group ($P<0.05$), with the combined group achieving a higher effective rate than the CTAR group ($P<0.05$). **Conclusion:** iTBS combined with CTAR can effectively improve swallowing function, enhance swallowing muscle strength, and increase quality of life in stroke patients with dysphagia.

Keywords: Deglutition disorders; Stroke; Rehabilitation; Transcranial magnetic stimulation; Intermittent theta burst stimulation; Randomized controlled trial

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Introduction

Stroke is a common neurological disorder, and dysphagia represents a frequent complication. Epidemiological data indicate that the incidence of dysphagia after stroke ranges from 35% to 85%, affecting approximately 46% of patients in the acute phase and 57% in the chronic phase. Post-stroke dysphagia not only compromises nutritional intake but also increases risks of aspiration, pulmonary infection, and psychological disorders, significantly impairing patients' quality of life. Current conventional swallowing training in clinical practice primarily includes direct training, indirect training, neuromuscular electrical stimulation, and acupuncture. While these interventions can improve swallowing function to some extent, their rehabilitative efficacy remains limited.

Chin tuck against resistance (CTAR) is a traditional exercise therapy widely used in dysphagia rehabilitation after stroke. CTAR improves swallowing function by strengthening the suprahyoid muscles and enhancing their coordination, offering advantages of good compliance and simple operation. However, swallowing involves the coordinated action of multiple muscle groups, nerves, and sensory systems, making it difficult for single-modality CTAR to comprehensively address swallowing dysfunction. Intermittent theta burst stimulation (iTBS)

is an emerging non-invasive brain stimulation technique that has shown therapeutic potential for post-stroke dysphagia. Nevertheless, clinical research on the combination of iTBS and CTAR for post-stroke dysphagia remains scarce. Therefore, this study aimed to investigate the effects of this combined intervention on swallowing function in stroke patients, providing a novel therapeutic approach for clinical practice.

Methods

1.1 Study Participants From March 2023 to July 2024, we enrolled 90 patients with post-stroke dysphagia at the Department of Rehabilitation Medicine of The First Affiliated Hospital of Bengbu Medical University. All patients had unilateral hemiplegia, with 33 having left hemisphere lesions and 57 having right hemisphere lesions. Participants were randomly assigned to three groups using a random number table: conventional group (n=30), CTAR group (n=30), and combined group (n=30). Baseline comparisons showed no significant differences among the three groups in gender, age, disease course, lesion side, or stroke type ($P>0.05$) .

Diagnostic Criteria: (1) Met the diagnostic criteria for stroke in the "Chinese Guidelines for the Diagnosis of Various Types of Cerebrovascular Diseases 2019" and was diagnosed with cerebral hemorrhage or infarction by MRI or CT imaging; (2) Dysphagia met the diagnostic criteria in the "Chinese Expert Consensus on Assessment and Treatment of Dysphagia (2017 Edition)."

Inclusion Criteria: (1) First-ever stroke with unilateral cerebral lesion only; (2) Disease course between 2 weeks and 3 months; (3) Age 50-80 years, regardless of gender; (4) Water swallow test grade $\geq$ III; (5) Stable vital signs and good consciousness; (6) Signed informed consent.

Exclusion Criteria: (1) History or family history of epilepsy; (2) Dysphagia caused by other conditions such as traumatic brain injury, brain tumor, head and neck tumors, or gastrointestinal tumors; (3) Implanted cardiac pacemaker or brain stimulator; (4) Severe cardiac, hepatic, or renal insufficiency; (5) Psychiatric disorders or visual/hearing impairments; (6) Craniectomy.

This study was approved by the Ethics Committee of The First Affiliated Hospital of Bengbu Medical University (Approval No. [2022] 323). All patients provided informed consent.

1.2 Treatment Methods All three groups received neurotrophic medication, conventional swallowing training, and rehabilitation nursing. Conventional swallowing training was conducted one-on-one by rehabilitation therapists blinded to group allocation.

1.2.1 Conventional Group: Received standard swallowing training including: (1) Lip closure exercises (lip pursing, smiling, cheek puffing, and tongue

depressor resistance training); (2) Tongue movement exercises (tongue tip movements in all directions, tongue flicking, and tongue rolling); (3) Ice stimulation (sequential stimulation of lips, tongue surface, pharyngeal wall, soft palate, and palatopharyngeal arch using iced cotton swabs); (4) Respiratory training (abdominal breathing, pursed-lip breathing, and blowing exercises); (5) Swallowing electrical stimulation using an HB61BE swallowing dysfunction therapy device (Suzhou Haobo Medical Equipment Co., Ltd.). Conventional training lasted 30 minutes per session, once daily, five times per week for four weeks.

1.2.2 CTAR Group: In addition to conventional rehabilitation training, patients received CTAR. The training method was as follows: Patients sat upright with an inflatable ball placed between the mandible and manubrium sterni, then compressed the ball forcefully with the mandible. The training included two modes: isokinetic training (30 consecutive compressions) and isometric training (compress and hold for 1 minute, followed by 1 minute rest). Each mode was performed for three sets daily, five times per week for four weeks.

1.2.3 Combined Group: In addition to CTAR, patients received iTBS using a YRD CCY-1 magnetic stimulator (Wuhan Yiruide Medical Device New Technology Co., Ltd.) with a 12.5 cm circular coil. Before the first iTBS session, each patient's resting motor threshold (RMT) was determined. To establish RMT, patients sat wearing a standard positioning cap, with hands relaxed and palms up on their thighs. Surface electrodes were placed with the reference electrode on the contralateral abductor pollicis brevis tendon, the recording electrode on the muscle belly, and the ground electrode on the proximal ipsilateral forearm. The coil center was positioned over the hand control area of the contralateral primary motor cortex (M1) to elicit motor evoked potentials of 0.5-1.0 mV peak-to-peak amplitude. The coil was slightly moved around the stimulation site to locate the "motor hotspot" that most easily elicited compound action potentials in the target muscle. With the coil position fixed, stimulation intensity was gradually decreased to identify the minimum intensity that produced responses of approximately 50 V in at least 5 out of 10 trials, which was defined as the RMT.

For iTBS treatment, patients lay supine wearing the standard positioning cap. The therapist placed the circular coil center over the cortical motor area of the suprahyoid muscles and secured it. The iTBS protocol consisted of: intraburst frequency 50 Hz, interburst frequency 5 Hz, stimulation duration 2 seconds, inter-train interval 8 seconds, repeated 20 times, totaling 600 pulses over 200 seconds at 80% RMT intensity. Treatment was administered once daily, five times per week for four weeks.

1.3 Observation Indicators Evaluations were conducted before treatment and after four weeks of intervention using the Standardized Swallowing Assessment (SSA), Functional Oral Intake Scale (FOIS), and sEMG measurements of maximum amplitude and swallowing duration in the suprahyoid muscle group.

1.3.1 SSA: This scale assesses swallowing function across three components: (1) Clinical examination (score range 8-23); (2) Observation of three 5 mL water swallows (score range 5-11); and (3) Observation of a single 60 mL water swallow (score range 5-12). Lower scores indicate better swallowing function.

1.3.2 FOIS: This scale evaluates oral feeding ability and autonomy, with total scores ranging from 1 to 7. Higher scores indicate better swallowing function.

1.3.3 Suprahyoid Muscle sEMG Acquisition: Using a MyoMove-EOW surface electromyography device (Shanghai Nuocheng Medical Equipment Co., Ltd.), patients sat upright with full neck exposure. The skin around the thyroid cartilage was cleaned with alcohol swabs, and disposable self-adhesive electrodes were placed bilaterally over the suprahyoid muscles (mylohyoid and digastric muscles) with the ground electrode on the left side. After establishing a stable baseline, patients were instructed to relax, then 5 mL of warm water was administered via syringe for swallowing while sEMG recorded swallowing duration and maximum amplitude. Each test was repeated three times and averaged.

1.3.4 Clinical Efficacy: Evaluated using the water swallow test. Patients sat and drank 30 mL of warm water while therapists observed and recorded drinking time and coughing episodes. Dysphagia was classified into five grades, with higher grades indicating better function. Efficacy criteria were: Grade 1 (no dysphagia) = cured; improvement by two grades = markedly effective; improvement by one grade = effective; no grade improvement = ineffective. Overall effective rate = (cured + markedly effective + effective cases) / total cases × 100%.

1.4 Statistical Analysis SPSS 25.0 software was used for data analysis. All measurement data were normally distributed and expressed as mean ± standard deviation ($\bar{x}\pm s$). Within-group comparisons used paired t-tests, between-group comparisons used one-way ANOVA, and pairwise comparisons used SNK-q tests. Count data were expressed as frequency (%) and compared using ^{2} tests. $P<0.05$ was considered statistically significant.

Results

2.1 Comparison of SSA Scores Among Three Groups Before treatment, no significant differences in SSA scores were observed among the three groups ($P>0.05$). After four weeks of treatment, SSA scores decreased significantly in all groups compared with baseline ($P<0.05$). Between-group comparisons at four weeks revealed significant differences ($P<0.05$), with the combined group showing lower scores than both the CTAR and conventional groups ($P<0.05$), and the CTAR group showing lower scores than the conventional group ($P<0.05$) .

2.2 Comparison of FOIS Scores Among Three Groups Baseline FOIS scores showed no significant differences among groups ($P>0.05$). After four

weeks, FOIS scores increased significantly in all groups compared with baseline ($P<0.05$). Post-treatment between-group comparisons revealed significant differences ($P<0.05$), with the combined group achieving higher scores than both the CTAR and conventional groups ($P<0.05$), and the CTAR group scoring higher than the conventional group ($P<0.05$) .

2.3 Comparison of sEMG Maximum Amplitude and Swallowing Duration No significant differences were found among groups in sEMG maximum amplitude or swallowing duration at baseline ($P>0.05$). After four weeks, all groups showed increased maximum amplitude and decreased swallowing duration compared with baseline ($P<0.05$). Between-group comparisons revealed significant differences ($P<0.05$), with the combined group demonstrating higher amplitude and shorter duration than both the CTAR and conventional groups ($P<0.05$), and the CTAR group showing better outcomes than the conventional group ($P<0.05$) .

2.4 Comparison of Clinical Efficacy After four weeks, significant differences in overall effective rates were observed among the three groups (^{2}=36.639, $P<0.05$). The combined group achieved a higher effective rate than both the CTAR and conventional groups (^{2}=14.292, $P<0.05$), while the CTAR group had a higher effective rate than the conventional group (^{2}=7.746, $P<0.05$) .

Discussion

The results demonstrate that all three treatment approaches improved SSA scores, FOIS scores, sEMG maximum amplitude, and swallowing duration after four weeks, indicating that each method can reduce dysphagia severity, enhance independent oral feeding ability, and improve quality of life. Surface electromyography provided objective assessment of neuromuscular improvements during swallowing, revealing enhanced muscle strength, increased muscle activity, and improved swallowing dynamics across all groups, with the most pronounced benefits in the combined group.

Neuroplasticity forms the foundation of central functional recovery. Based on the "central-peripheral-central" closed-loop rehabilitation concept, combining central interventions that activate functional brain regions with peripheral interventions that strengthen sensorimotor control can effectively promote motor pattern memory and regulation. CTAR serves as a peripheral intervention that effectively activates suprahyoid muscles, promotes upper esophageal sphincter opening, and improves swallowing function—an effect validated in previous studies. CTAR recruits motor units in swallowing muscles and stimulates suprahyoid muscle contraction, thereby enhancing pharyngeal phase swallowing function. Our findings align with these conclusions, showing superior muscle activation in the CTAR group compared with conventional training.

As a special stimulation mode of repetitive transcranial magnetic stimulation, iTBS incorporates rhythmic burst pulses, offering advantages of minimal ad-

verse effects and high efficiency. Meta-analyses have demonstrated the safety and efficacy of repetitive transcranial magnetic stimulation for post-stroke dysphagia. iTBS can improve swallowing motor processes, promote neural functional reorganization in the affected hemisphere, and facilitate swallowing recovery. Consistent with these findings, our results show that iTBS applied to the pharyngeal motor cortex of the affected hemisphere significantly improved dysphagia symptoms, with effects lasting up to three months.

After four weeks, the combined group demonstrated superior outcomes in overall effective rate, SSA scores, FOIS scores, sEMG maximum amplitude, and swallowing duration compared with both the CTAR and conventional groups. This suggests that iTBS combined with CTAR enhances swallowing muscle strength, improves overall swallowing coordination, promotes reconstruction and strengthening of swallowing reflexes, and reinforces normal swallowing motor control, thereby facilitating nutritional intake and reducing aspiration risk. The therapeutic effect extends beyond single-modality neural regulation or muscle strengthening, achieving enhanced swallowing capacity through coordinated central-peripheral interaction.

The underlying mechanism may involve iTBS providing an efficient neural regulatory foundation for CTAR, while peripheral muscle strengthening through CTAR consolidates central neuroplasticity effects. iTBS activates the affected cerebral cortex, enhancing neuroplasticity and making swallowing actions more readily activated and regulated at the neural level. This enhanced neuroplasticity optimizes peripheral muscle responsiveness to central neural control. During CTAR resistance training, suprahyoid muscles achieve functional strengthening under iTBS neural modulation, demonstrating more efficient muscle synergy that improves laryngeal elevation and muscle strength, accelerating swallowing recovery. In summary, combined iTBS and CTAR therapy demonstrates synergistic effects of central neural regulation and peripheral muscle reinforcement, forming a dual-promotion mechanism in dysphagia rehabilitation. Compared with single therapies, this combined approach not only more comprehensively improves swallowing function but also shortens rehabilitation duration and enhances treatment durability, offering a more effective and comprehensive solution for dysphagia management.

This study has several limitations, including a relatively small sample size, short follow-up period, and homogeneous patient population. Future research should expand sample sizes, extend follow-up durations, and validate findings across diverse patient populations to ensure broad applicability and long-term efficacy. Additionally, future studies should explore optimal treatment parameters for combined iTBS and CTAR therapy, including stimulation intensity, frequency, and training duration.

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Author Contributions: Xue Han was responsible for study conception and design, implementation, and manuscript writing. Huan Liu, Xiaole Lou, and Jianing Song conducted scale assessments and data organization. Ziang Zhang and Zongxiao Geng recruited participants. Shan Wang collected transcranial magnetic stimulation data. Yongqing Zhang performed statistical analysis. Lei Xu was responsible for quality control and overall supervision. All authors approved the final manuscript.

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Note: Figure translations are in progress. See original paper for figures.