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The Impact of Different Rehabilitation Training Modes on VHI Scores and MPT in Patients with Post-Stroke Dysphonia: A Case Study of Visual Glottal Closure Training

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Abstract: *Objective*: To systematically evaluate the effects of visual glottal closure training guided by swallowing electronic laryngoscopy and conventional voice training on the Voice Handicap Index (VHI) scores and Maximum Phonation Time (MPT) in patients with post-stroke dysphonia (PSD), providing evidence-based support for precise rehabilitation in such patients. *Methods*: A randomized controlled trial design was employed, selecting patients with post-stroke dysphonia who met the inclusion criteria as the study subjects. Patients were randomly divided into an experimental group (receiving visual glottal closure training) and a control group (receiving conventional voice training), with 32 cases in each group. Both groups underwent training for 8 weeks, twice a week, with each session lasting 30 minutes. The VHI scale was used to assess the subjective degree of voice impairment, and MPT was measured to evaluate vocal efficiency at four time points: baseline (T0), mid-treatment (T1, 4 weeks), end of treatment (T2, 8 weeks), and follow-up 3 months after treatment (T3). Statistical analysis was performed on the data. *Results*: A total of 64 patients were included, with 58 completing the study (29 in the experimental group and 29 in the control group), resulting in a dropout rate of 9.38%. There were no statistically significant differences in VHI scores and MPT between the two groups at baseline (T0) ($P > 0.05$). During the mid-treatment phase (T1), at the end of treatment (T2), and during the follow-up period (T3), the Voice Handicap Index (VHI) scores of patients in both groups significantly decreased compared to the baseline period ($P < 0.05$), and the Maximum Phonation Time (MPT) significantly increased compared to the baseline period ($P < 0.05$). Moreover, the VHI scores of the experimental group at each time point (T1: 42.35 points vs. 56.82 points, T2: 28.16 points vs. 45.73 points, T3: 25.48 points vs. 41.95 points) were significantly lower than those of the control group ($P < 0.05$), and the MPT (T1: 12.68s vs. 9.35s, T2: 16.82s vs. 11.57s, T3: 15.96s vs. 10.83s) was significantly longer than that of the control group ($P < 0.05$). *Conclusion*: Both visual glottal closure training guided by swallowing electronic laryngoscopy and conventional voice training can improve the subjective voice impairment and vocal efficiency of patients with post-stroke dysphonia. However, visual glottal closure training demonstrates superior efficacy and sustained therapeutic effects, making it a preferred rehabilitation option for patients with post-stroke dysphonia.

Keywords: Post-stroke dysphonia; Visual glottal closure training; Conventional voice training; Voice handicap index; Maximum phonation time

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1. Introduction

Post-stroke dysphonia (PSD), a voice disorder that receives relatively little attention among stroke patients, is gradually gaining recognition from researchers regarding its pathogenesis, rehabilitation approaches, and efficacy evaluation. Its pathological mechanisms primarily involve central nervous system damage, leading to manifestations such as incomplete glottal closure, air leakage during phonation, rough voice quality, unstable fundamental frequency, and shortened Maximum Phonation Time (MPT) [1,2]. Voice disorders not only interfere with patients' verbal communication, social participation, and return to work but may also increase the risk of aspiration due to decreased glottal closure function and impaired control of respiratory airflow, thereby affecting overall rehabilitation outcomes [3]. Currently, most of the commonly used clinical intervention methods still rely on acoustic/auditory imitation training, respiratory support training, resonance/soft and hard onset exercises, vocal posture correction, behavioral therapy, and glottal thrust techniques [4,5]. These traditional training methods depend on therapists' verbal instructions or auditory imitation and are suitable for voice disorders caused by functional issues or abnormal vocal muscle tension. However, for stroke patients, due to central sensorimotor integration disorders, diminished proprioceptive feedback, and reduced motor control precision, it is more challenging for them to accurately perform the delicate glottal closure movements based solely on auditory or verbal instructions, resulting in poor training compliance and significant variations in treatment efficacy. This study employed a rigorously designed randomized controlled trial to compare and analyze the effects of visual glottal closure training guided by swallowing videolaryngoscopy versus conventional voice training on the Voice Handicap Index (VHI) scores and Maximum Phonation Time (MPT) of stroke patients with voice disorders. The aim is to provide high-quality evidence-based support for developing precise and individualized rehabilitation plans for stroke patients with voice disorders and to promote the advancement of rehabilitation research for post-stroke communication disorders towards evidence-based, individualized, and visual approaches.

2. Materials and methods

2.1. Study subjects

This study was a single-center, randomized controlled trial. The study subjects were patients with post-stroke voice disorders admitted to the neurology and rehabilitation medicine departments of a certain hospital from March 2025 to September 2025. Using the Voice Handicap Index (VHI) as the primary outcome measure, and referring to previous studies [5], with α set at 0.05, β at 0.2, an inter-group difference of 10 points, and a standard deviation of 12 points, G-Power calculations indicated that 27 cases were required per group. Considering a 20% dropout rate, 32 cases were included in each group, totaling 64 cases. Inclusion criteria were as follows: (1) confirmed cerebral infarction/hemorrhage by CT/MRI, in accordance with relevant guidelines; (2) stable condition 1-6 months post-stroke; (3) VHI score ≥ 18 points, laryngoscopy showing glottal closure ≥ grade 3, and maximum phonation time (MPT) < 10 seconds (males)/8 seconds (females); (4) Mini-Mental State Examination (MMSE) score ≥ 24 points, able to cooperate with training; (5) informed consent obtained. Exclusion criteria included: (1) severe aspiration (VFSS ≥ grade 4/FEES ≥ 8 points); (2) severe aphasia (WAB < 30 points); (3) non-stroke-related voice disorders; (4) severe underlying medical conditions; (5) receipt of other voice interventions within the past month; (6) psychiatric/cognitive disorders or intolerance to laryngoscopy.

2.2. Methods

Both groups of patients received interventions from speech therapists who had undergone uniform training and passed consistency assessments. The training frequency was twice a week, with each session lasting 30 minutes, for a total duration of 8 weeks.

2.2.1. Experimental group

The entire training process is conducted under the guidance of a swallowing electronic laryngoscope (Model: OLYMPUS ENF-VT3), with specific training content divided into the following three stages, totaling 30 minutes:

2.2.1.1. Relaxation and breathing preparation (5 minutes)

Instruct the patient in abdominal breathing exercises: The patient assumes a comfortable seated position, placing one hand on the chest and the other on the abdomen. During inhalation, the abdomen expands, and during exhalation, it contracts. Repeat the training, controlling each breath to last between 4 to 6 seconds. Simultaneously, perform neck and laryngeal muscle massage and relaxation: The therapist gently massages the muscles on both sides of the patient's neck and the area around the larynx, from below the jaw to the suprasternal notch, for 30 seconds at each location, helping the patient relieve tension in the laryngeal muscles.

2.2.1.2. Core training guided by electronic laryngoscope (20 minutes)

(1) Perception stage (5 minutes): Insert the swallowing electronic laryngoscope through the patient's nasal cavity or oral cavity to clearly display the patient's glottal structure on the screen. Allow the patient to observe the glottal morphology during quiet breathing and sustained vowel production of "I" (lasting 3 to 5 seconds). The therapist, in conjunction with the screen images, explains in detail to the patient the normal glottal closure morphology and the areas where the patient's own glottal closure is incomplete (such as spindle-shaped or triangular gaps), helping the patient establish perception of their own glottal activity.

(2) Imitation and adjustment stage (10 minutes): The goal is to achieve a transition from the patient's current glottal gap morphology (spindle-shaped or triangular) to linear closure. The therapist guides the patient to attempt the action of "gentle coughing", allowing the patient to observe the state of glottal closure at the moment of coughing. Then, the therapist leads the patient to grasp the sensation of glottal closure and translate it into vocalization. Alternatively, the therapist may instruct the patient in "flute-like" gentle onset training, where the patient mimics the action of blowing a flute, vocalizing slowly, and adjusting the degree of glottal closure with real-time feedback on the screen to ensure gradual improvement in glottal closure. During the training process, the therapist provides real-time guidance and encouragement based on the patient's performance, allowing the patient to rest for 10-15 seconds after each effective training session.

(3) Advanced training (5 minutes): Once the patient can adequately control glottal closure during vowel vocalization under laryngoscope guidance, the difficulty of the training is gradually increased. Starting with sustained vowel production (e.g., "I", "ɑ"), the duration is gradually increased from 3 seconds to 5 seconds. Then, the patient transitions to producing disyllabic words (e.g., "mama", "baba"), polysyllabic words (e.g., "library", "television"), and finally engages in short sentence reading

exercises (e.g., "The weather is really nice today", "I want to train well"). Throughout the advanced training process, the patient is required to continuously focus on the glottal image displayed on the screen, adjusting their vocalization method based on real-time feedback to ensure good glottal closure.

2.2.1.3. Consolidation and generalization (5 minutes)

The swallowing electronic laryngoscope is removed, and the patient is asked to recall the sensation of glottal closure under laryngoscope guidance and attempt to reproduce the correct vocalization method. The therapist selects short, easy-to-understand passages (such as excerpts from children's stories, approximately 50 words in length) for patients to engage in oral reading exercises. During the patient's reading, the therapist uses auditory perception to assess the patient's vocalization and provides prompt feedback and corrections in a timely manner, helping the patient generalize the glottal control skills acquired during training to daily verbal communication.

2.2.2. Control group

The training content, duration, and frequency are identical to those of the experimental group, but without the use of swallowing electronic laryngoscopy for visual feedback throughout the process. The therapist guides the patient's training solely through verbal instructions, tactile feedback, and auditory imitation:

2.2.2.1. Relaxation and breathing preparation (5 minutes)

Abdominal breathing training methods are the same as those in the experimental group; relaxation of the neck and laryngeal muscles is achieved through verbal guidance, where the therapist informs the patient of the areas and methods to relax, allowing the patient to perform muscle relaxation exercises independently. The therapist assesses the patient's muscle relaxation through palpation and makes adjustments if necessary.

2.2.2.2. Regular core training (20 minutes)

(1) Auditory imitation training (5 minutes): The therapist demonstrates the correct vocalization of sustained vowels "I" and "ɑ", instructing the patient to imitate the therapist's voice through auditory perception. Based on the patient's vocalization, the therapist provides verbal instructions (such as "make your voice louder" or "make your breath steadier") to guide the patient in adjusting their vocalization.

(2) Coordinated training of breathing and vocalization (10 minutes): Guide patients in vocalization exercises supported by breathing. Instruct patients to take a deep breath and then slowly vocalize vowels. The therapist provides tactile feedback (e.g., placing a hand on the patient's abdomen to feel the rise and fall during breathing) and verbal instructions to help patients coordinate their breathing and vocalization. Simultaneously, conduct contrast exercises between hard onset and soft onset: The therapist demonstrates the vocalization methods for hard onset (e.g., when vocalizing the sound "ba", the vocal cords close rapidly, resulting in a forceful start of the sound) and soft onset (e.g., when vocalizing the sound "ma", the vocal cords close slowly, resulting in a gentle start of the sound). Patients are asked to imitate these exercises, and the therapist uses auditory judgment to assess the correctness of the patients' onset methods and provides guidance accordingly.

(3) Advanced training (5 minutes): This is consistent with the advanced training content of the experimental group, transitioning from vowel vocalization to word and short sentence reading exercises. However, the therapist only guides the patient's training through verbal instructions and auditory feedback, such

as “Pronounce words clearly” and “Read short sentences smoothly”.

2.2.2.3. Consolidation and generalization (5 minutes)

Similar to the experimental group, patients are asked to engage in oral reading exercises of short passages. The therapist provides guidance on aspects such as vocalization and speech clarity through auditory feedback to help patients consolidate the training effects.

2.3. Observation indicators

At four time points—the baseline period (T0, within 1 week before the start of training), mid-treatment (T1, after 4 weeks of training), the end of treatment (T2, after 8 weeks of training), and the 3-month follow-up after treatment (T3, 3 months after the end of training)—the following indicators were evaluated in both groups of patients:

2.3.1. Voice handicap index (VHI) score

The evaluation was conducted using the internationally recognized Chinese version of the VHI scale. This scale comprises three dimensions—functional, emotional, and physiological—with a total of 30 items. Each item employs a Likert 5-point rating scale, with a total score range of 0-120 points. A higher score indicates a more severe subjective voice handicap in the patient.

2.3.2. Maximum phonation time (MPT)

This was assessed using objective measurement methods. Patients were seated comfortably with their upper bodies upright. The therapist instructed the patient to take a deep breath and then sustain the vowel sound “ɑ” at a comfortable pitch and volume. Simultaneously, a stopwatch (precision: 0.01 seconds) was used to record the duration of phonation. The measurement was repeated three times, and the average value was taken as the patient’s MPT value, measured in seconds (s). A longer MPT value indicates better respiratory support and phonation efficiency in the patient.

2.3.3. Glottal closure function

Under electronic laryngoscopy for swallowing, dynamic glottal images were recorded while the patient was producing the sustained vowel “I” (with a duration of 3 to 5 seconds). Two senior speech therapists, unaware of the patient grouping, and each with over 5 years of clinical experience in voice rehabilitation, independently rated the images using a blinded method. The rating criteria referred to the glottal closure grading scale: Grade 1: complete closure, no glottal gap; Grade 2: nearly complete closure, with a tiny glottal gap (width < 1 mm); Grade 3: incomplete closure, with a noticeable glottal gap (width 1–2 mm); Grade 4: severely incomplete closure, with a wide glottal gap (width > 2 mm).

2.4. Statistical methods

Data analysis was performed using SPSS 27.0 statistical software. Measurement data conforming to a normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm s$). Comparisons at different time points within the same group were conducted using repeated measures analysis of variance, while comparisons at the same time point between groups were performed using independent sample t-tests. Categorical data were expressed as the number of cases (percentage) [n (%)], and ordinal data comparisons were made using the Mann-Whitney U test. Sample size estimation was performed using G-Power 3.1.9.2 software. All statistical tests were two-tailed, and a P-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of baseline data

There were no significant differences between the two groups in terms of gender, age, stroke type, onset time, VHI, MPT, or glottal closure grade ($P > 0.05$), indicating comparability (**Table 1**).

Table 1. Comparison of baseline data between the two groups

Item		Experimental Group (*n* = 29)	Control Group (*n* = 29)	t/χ^2/Z Value	*P* Value
Gender (Male/Female, n)		16/13	15/14	0.07	0.791
Age (years, mean ± SD)		52.35 ± 7.82	53.12 ± 8.05	0.36	0.721
Stroke Type (n, %)	Ischemic	21 (72.41)	20 (68.97)	0.08	0.776
	Hemorrhagic	8 (27.59)	9 (31.03)		
Time Since Onset (months, mean ± SD)		3.28 ± 1.15	3.42 ± 1.21	0.45	0.655
VHI Score (points, mean ± SD)		68.52 ± 8.36	67.93 ± 8.51	0.25	0.804
MPT (s, mean ± SD)		6.85 ± 1.23	6.72 ± 1.18	0.41	0.683
Glottal Closure (n, %)	Grade 1	0 (0.00)	0 (0.00)	0.18	0.856
Grade 2	Grade 2	3 (10.34)	2 (6.90)		
Grade 3	Grade 3	18 (62.07)	19 (65.52)		
Grade 4	Grade 4	8 (27.59)	8 (27.59)		

3.2. Comparison of VHI scores between the two groups

The VHI scores of the experimental group were lower than those of the control group at all time points ($P < 0.05$) (**Table 2**).

Table 2. Comparison of VHI scores between the two groups at different time points (mean ± SD, points)

Group	T0 (Baseline)	T1 (Post-treatment 1)	T2 (Post-treatment 2)	T3 (Follow-up)
Experimental Group (*n* = 29)	68.52 ± 8.36	42.35 ± 7.18	28.16 ± 6.54	25.48 ± 5.97
Control Group (*n* = 29)	67.93 ± 8.51	56.82 ± 7.63	45.73 ± 7.02	41.95 ± 6.84
t value	0.25	8.13	9.27	8.85
P value	0.804	< 0.001	< 0.001	< 0.001

3.3. Comparison of MPT between the two groups

The MPT of the experimental group was longer than that of the control group at all time points ($P < 0.05$) (**Table 3**).

Table 3. Comparison of MPT between the two groups at different time points (mean ± SD, s)

Group	T0 (Baseline)	T1	T2	T3
Experimental	6.85 ± 1.23	12.68 ± 1.57	16.82 ± 1.84	15.96 ± 1.72
Control	6.72 ± 1.18	9.35 ± 1.32	11.57 ± 1.46	10.83 ± 1.39
t value	0.41	8.92	10.76	10.23
P value	0.683	< 0.001	< 0.001	< 0.001

3.4. Comparison of glottal closure function between the two groups

There was no significant difference in grading between the two groups at T0 ($P = 0.856$); the experimental group had a higher proportion of grades 1-2 at T1-T3 ($P < 0.05$). At T2, 86.21% of the experimental group were in grades 1-2, compared to 55.17% in the control group (**Table 4**).

Table 4. Distribution of glottal closure grades in the two groups (cases, %)

Grade	Group	T0 (Baseline)	T1	T2	T3
Grade 1	Experimental	0 (0.00)	5 (17.24)	14 (48.28)	12 (41.38)
	Control	0 (0.00)	1 (3.45)	4 (13.79)	3 (10.34)
Grade 2	Experimental	3 (10.34)	12 (41.38)	11 (37.93)	13 (44.83)
	Control	2 (6.90)	8 (27.59)	12 (41.38)	10 (34.48)
Grade 3	Experimental	18 (62.07)	10 (34.48)	4 (13.79)	4 (13.79)
	Control	19 (65.52)	15 (51.72)	11 (37.93)	14 (48.28)
Grade 4	Experimental	8 (27.59)	2 (6.90)	0 (0.00)	0 (0.00)
	Control	8 (27.59)	5 (17.24)	2 (6.90)	2 (6.90)
Z-value	-	0.18	2.95	4.12	3.87
P-value	-	0.856	0.003	< 0.001	< 0.001

4. Discussion

In recent years, research on the application of integrated respiratory-voice training methods in stroke populations has shown initial success. A 2021 retrospective study demonstrated that for patients with voice disorders following stroke, a 28-day program of combined respiratory muscle training (cRMT) resulted in significant improvements in the intervention group compared to the control group in terms of maximum expiratory flow rate, self-perceived voice improvement, CAPE-V auditory-perceptual evaluation scores, and MPT [6]. Such studies suggest that strengthening the respiratory muscle groups can enhance the foundation of vocal airflow, providing more stable support for glottal closure and vocal cord vibration. Research on the correlation between nutritional biomarkers and vocal function is also gradually increasing. A 2023 study in South Korea analyzing 180 patients with ischemic stroke found that serum transferrin, albumin, and prealbumin levels were significantly correlated with the Dysphonia Severity Index (DSI), with prealbumin and transferrin serving as independent predictors of DSI. This study indicates that post-stroke voice disorders are influenced not only by local motor control of the glottis and vocal cords but also by systemic factors such as overall metabolic and nutritional status and the body's repair capacity, suggesting that rehabilitation research should incorporate a broader range of biomedical indicators [7].

Simultaneously, the role of sensorimotor integration mechanisms in voice control is receiving increasing attention. A 2024 review examining 17 relevant studies from 2000 to 2023 highlighted the central role of sensorimotor integration in vocal regulation and emphasized the importance of visual, tactile, and auditory feedback in the process of voice learning [8]. Although this review did not specifically focus on stroke populations, its theoretical framework provides a crucial basis for developing vocal training strategies based on multimodal feedback. Building on this foundation, training techniques supported by visualization and real-time feedback, while still in the preliminary exploration stage for post-stroke voice rehabilitation, are showing significant potential for development. A retrospective study in China compared the effects of systematic vocalization training combined with swallowing exercises versus swallowing training alone in stroke patients, finding that the combined intervention group demonstrated superior outcomes in swallowing function, incidence of aspiration pneumonia, and quality of life. Although this study did not focus on visual feedback training for glottal morphology, its results reflect the potential value of vocalization training in comprehensive stroke rehabilitation [9]. Furthermore, research in the field of phonetics has explored the use of laryngoscopic imaging, high-speed videography, or real-time acoustic analysis in interventions for functional vocal disorders. For example, combining conventional training with laryngoscopic observation can effectively improve glottal closure patterns and acoustic parameters [10]. These technological approaches provide a methodological foundation for developing objective and individualized voice rehabilitation programs.

From a neurophysiological perspective, central voice disorders caused by stroke are fundamentally due to damage to the cortical vocal motor areas (such as the posterior inferior frontal gyrus and insula) and subcortical pathways (such as the basal ganglia and brainstem), resulting in sensorimotor integration disorders in glottal motor control. Conventional voice training relies on auditory feedback and proprioception, but stroke patients often experience diminished proprioception, leading to “perception-action” matching errors and difficulty in precisely adjusting glottal closure movements. Visualized glottal closure training, through real-time imaging via swallowing electronic laryngoscopy, transforms the invisible physiological process of glottal movement into intuitive visual signals, directly activating the collaborative function of the parietal visual association cortex and motor cortex in the brain, thereby enhancing the perceptual accuracy of glottal closure status.

In this study, after 8 weeks of treatment, the Voice Handicap Index (VHI) score in the experimental group decreased to 28.16 ± 6.54 points, representing a 58.90% reduction from the baseline and significantly lower than the control group’s score of 45.73 ± 7.02 points (a 32.68% reduction). This indicates that visual training can more effectively alleviate patients’ subjective discomfort. From a clinical practice perspective, when the VHI score decreases by more than 20 points, patients’ communication confidence and willingness to participate in social activities significantly increase. The experimental group reached this threshold at the T2 time point, whereas the control group did not meet this criterion even by the follow-up period (with a reduction of 25.98 points), suggesting that visual training offers greater advantages in improving patients’ subjective experiences.

This study has the following limitations: Firstly, it was a single-center study with a relatively limited sample size (n = 58) and did not consider the impact of stroke lesion location (e.g., left hemisphere vs. right hemisphere) on training effectiveness. Future research should involve multi-center, large-sample studies and incorporate imaging examinations (such as fMRI) to analyze the correlation between lesion location and treatment efficacy. Secondly, the study did not include indicators such as the Activities of Daily Living (ADL) score, making it impossible to comprehensively evaluate the impact of voice rehabilitation on patients’ overall quality of life. Subsequent studies could incorporate such indicators. Finally, the follow-up period in this study was only 3 months, and the long-term efficacy (e.g., at 6 months and 12 months) still requires further observation.

5. Conclusion

In conclusion, both the visual glottal closure training guided by swallowing electronic laryngoscope and conventional voice training can improve the subjective voice disorder severity (as indicated by a decrease in the Voice Handicap Index (VHI) score), vocal efficiency (as evidenced by an extension of the Maximum Phonation Time (MPT)), and glottal closure function in patients with post-stroke voice disorders. However, the visual glottal closure training demonstrates more significant effects and maintains its efficacy for over three months. Therefore, visual glottal closure training can be considered as a preferred rehabilitation treatment option for patients with post-stroke voice disorders and is worthy of clinical promotion and application.

Disclosure statement

The authors declare no conflict of interest.

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