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Construction and Application of Early Rehabilitation Protocol for Post-stroke Dysphagia Based on the Closed-loop Management of "Assessment-Intervention-Monitoring"

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Abstract: *Objective:* To analyze the efficacy and clinical value of an early rehabilitation protocol based on the closed-loop management mode of "Assessment-Intervention-Monitoring" in patients with post-stroke dysphagia. *Methods:* A total of 78 patients with post-stroke dysphagia admitted to our hospital from October 2023 to October 2024 were enrolled and randomly divided into two groups by the random number table method, with 39 cases in each group. The control group received routine rehabilitation treatment, while the observation group adopted the early rehabilitation protocol based on the closed-loop management of "Assessment-Intervention-Monitoring". Nutritional indicators and immune function were compared between the two groups. *Results:* After treatment, the nutritional status of both groups was significantly improved compared with baseline ($P < 0.05$). The incidence of complications in the observation group was lower than that in the control group ($P < 0.05$). In terms of immune function indexes and clinical effectiveness rate, the observation group was significantly superior to the control group ($P < 0.05$). *Conclusion:* For patients with post-stroke dysphagia, the early rehabilitation protocol based on "Assessment-Intervention-Monitoring" closed-loop management can effectively improve nutritional status and immune function, reduce complications, and enhance the comprehensive therapeutic effect.

Keywords: Closed-loop management; Early rehabilitation protocol; Stroke; Dysphagia

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1. Introduction

Stroke is a severe neurological disease threatening human health worldwide. It interrupts cerebral blood supply and results in impairments of cognition, language, swallowing and limb motor function. Among these sequelae, dysphagia not only interferes with patients' normal oral intake, but also causes complications such as dehydration, malnutrition and aspiration pneumonia, which may be lifethreatening in severe cases [1]. At present, conventional clinical rehabilitation mainly focuses on the recovery of limb movement and vital signs, while the assessment and intervention of swallowing function are often initiated relatively late. Moreover, it lacks individualized and dynamic adjustment mechanisms, leading to unsatisfactory rehabilitation outcomes. In recent years, the concept of early rehabilitation has gained increasing attention; nevertheless,

existing protocols still present problems such as disconnection among the links of **assessment–intervention–monitoring** and insufficient interdisciplinary collaboration. Therefore, based on the theory of closedloop management, this study constructed an integrated early rehabilitation protocol covering assessment, intervention and monitoring. By means of dynamic evaluation, targeted intervention and continuous monitoring, a systematic rehabilitation closed loop was established. With a randomized controlled design enrolling patients with poststroke dysphagia, this study observed the effects of the protocol on nutritional status, immune function, complication incidence and clinical efficacy, so as to provide evidencebased references for optimizing rehabilitation strategies for poststroke dysphagia. The purpose of this paper is to verify the clinical application value of this early rehabilitation protocol based on closedloop management.

2. Materials and methods

2.1. General data

A total of 78 patients with post-stroke dysphagia admitted to Huishan District Rehabilitation Hospital of Wuxi from October 2023 to October 2024 were enrolled as the research subjects. They were divided into the observation and control groups by the random number table method, with 39 cases in each group. There were no statistically significant differences in the general data (gender, age, disease course) between the two groups ($P > 0.05$), indicating baseline comparability, as shown in **Table 1**. This study was approved by the Medical Ethics Committee of the hospital, and informed consent was signed by all patients or their family members. Sample size estimation was based on the preliminary experiment, with an effective rate of 85% in the observation group and 60% in the control group. Setting $\alpha = 0.05$ and $\beta = 0.20$, the calculated minimum sample size was 36 cases per group. Considering a 10% dropout rate, 39 cases were finally included in each group.

Table 1. Baseline general data (mean ± SD), case (%)

Group	n	Male/Female	Age (years)	Disease course (d)
Observation group	39	22/17	59.26 ± 2.05	4.01 ± 0.33
Control group	39	20/19	59.34 ± 2.43	4.15 ± 0.27
t/χ2	—	0.206	0.157	0.915
P	—	0.649	0.875	0.106

2.2. Inclusion and exclusion criteria

Inclusion criteria: (1) Patients met the diagnostic criteria for stroke specified in the "*Chinese Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke 2018"* [2] and "*Chinese Guidelines for the Diagnosis and Treatment of Cerebral Hemorrhage 2019*," and the diagnosis was confirmed by cranial CT or MRI; (2) Stable vital signs and clear consciousness; (3) Grade 3 or above according to the Kubota Water Swallowing Test, with definite swallowing dysfunction. Exclusion criteria: Patients complicated with severe pulmonary infection, consciousness disorder, or inability to cooperate with rehabilitation training; those with severe insufficiency of cardiac, hepatic, renal and other vital organs; those complicated with other neurological or psychiatric diseases leading to poor cooperation; and those who refused to sign the informed consent form.

2.3. Methods

The control group received routine rehabilitation treatment, including pharmacological interventions such as circulation improvement and neurotrophic therapy. Patients were given a liquid diet via nasogastric tube. Basic oral massage and passive swallowing stimulation were performed by rehabilitation therapists once a day for 20 minutes each time, with a continuous treatment course of 4 weeks.

The observation group was administered an early rehabilitation protocol based on the closed-loop management model

of **Assessment–Intervention–Monitoring**, with specific measures as follows.

(1) Prior assessment and protocol formulation: Within 24 hours after admission, the Kubota water swallowing test, videofluoroscopic swallowing study (VFSS), and clinical swallowing evaluation were completed to clarify the type and severity of dysphagia. An individualized rehabilitation plan was jointly formulated by rehabilitation physicians, speech therapists and dietitians.

(2) Targeted intervention and closed-loop training:

(a) Muscle training: Tongue resistance training (press the tongue body down with a tongue depressor, and ask the patient to lift the tongue upward with maximum effort; 10 times per set, 2 sets per day); buccinator muscle training (bulge both cheeks and maintain for 5 seconds, repeated 10 times); laryngeal elevation training (falsetto phonation practice and laryngeal lifting resistance training; 5 times per set, 2 sets per day).

(b) Posture adjustment: According to the VFSS results, compensatory swallowing postures such as chin-down swallowing (chin close to the sternum) or head-turning swallowing (turn the head toward the affected side) were adopted, with 5 minutes of training per meal.

(c) Swallowing exercises: Alternating training of dry swallowing and saliva swallowing (5 minutes each time, 3 times per day); effortful swallowing (instruct patients to forcibly squeeze the tongue base and posterior pharyngeal wall).

(d) Oral and pharyngeal rehabilitation: Ice cotton swabs were used to stimulate the soft palate, tongue base and posterior pharyngeal wall, twice a day for 5 minutes each time; breathing training (abdominal breathing and forced exhalation), twice a day with 10 breaths per session. The total duration of the above training was 30 minutes each session, twice a day, 5 days a week, for a continuous course of 4 weeks.

(3) Nutritional support and interdisciplinary collaboration: Dietitians formulated individualized dietary regimens (such as paste-like food and soft food) according to patients' nutritional status and dietary preferences, and guided family members in implementation. A multidisciplinary team meeting was held once a week to adjust the rehabilitation protocol.

(4) Continuous monitoring and dynamic adjustment: Events such as choking during eating and aspiration were recorded daily. The Kubota Water Swallowing Test and nutritional indicators were re-evaluated every week, and VFSS examination was performed every two weeks. Training intensity and postural strategies were timely adjusted based on monitoring outcomes, so as to form a closed-loop management mode of **assessment–intervention–monitoring**.

2.4. Observation indicators

(1) Nutritional status indicators: Fasting elbow venous blood of 5 mL was collected from all patients in the early morning before treatment and after 4 weeks of treatment. The levels of serum total protein, hemoglobin and albumin were determined by nephelometry.

(2) Incidence of complications: The cases of aspiration, aspiration pneumonia, abdominal distension and diarrhea in the two groups during treatment were recorded, and the total incidence rate was calculated. Aspiration was defined as choking or dyspnea occurring during eating or training; aspiration pneumonia was confirmed by chest imaging examination.

(3) Immune function indicators: Enzyme-linked immunosorbent assay (ELISA) was adopted to detect serum IgG and IgM levels before and after treatment. The assay kits were purchased from Shanghai Enzyme-linked Biotechnology Co., Ltd. , and all operations were performed strictly in accordance with the manufacturer's instructions.

(4) Clinical efficacy: The Kubota Water Swallowing Test was used to evaluate swallowing function before and after treatment. Markedly effective: swallowing function improved by grade 2 or above; Effective: swallowing function improved by grade 1; Ineffective: no improvement or deterioration. Total effective rate = (Markedly effective cases + Effective cases) / Total cases × 100%.

2.5. Statistical analysis

SPSS 25.0 software was used for data analysis. Measurement data conforming to the normal distribution were expressed as mean ± standard deviation (SD), and independent sample *t*-test was adopted for inter-group comparison. Enumeration data were presented as case (%), and the chi-square (χ^2) test was used for comparison between groups. A *P* value less than 0.05 was considered statistically significant.

3. Results

3.1. Nutritional status indicators

Before treatment, there were no statistically significant differences in the levels of serum total protein, hemoglobin and albumin between the two groups ($P > 0.05$). After treatment, the above three indicators in the observation group were significantly higher than those in the control group, with statistical differences ($P < 0.05$). Compared with the baseline in the same group, the nutritional indicators of both groups were significantly improved after treatment ($P < 0.05$). See **Table 2**.

Table 2. Nutritional status indicators (mean ± SD, g/L)

Group	n	Total serum protein		Hemoglobin		Albumin	
		Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Observation group	39	60.15 ± 4.28	65.64 ± 7.80	89.12 ± 2.80	97.61 ± 5.36	30.21 ± 3.25	35.14 ± 4.70
Control group	39	60.11 ± 4.30	61.39 ± 7.21	89.15 ± 2.77	92.13 ± 3.48	30.18 ± 3.85	32.11 ± 4.10
t	—	0.041	2.498	0.047	5.355	0.037	3.033
P	—	0.967	0.014	0.962	0.000	0.970	0.003

Note: Compared with the pre-treatment level in the same group, $P < 0.05$.

3.2. Complications

The total incidence rate of complications in the observation group was 5. 13%, which was significantly lower than 23.08% in the control group, and the difference was statistically significant ($\chi^2 = 5.185$, $P = 0.022$). See **Table 3**.

Table 3. Incidence of complications [n(%)]

Group	n	Aspiration	Aspiration Pneumonia	Abdominal Distension and Diarrhea	Total Incidence Rate (%)
Observation group	39	1(2.56)	0(0.00)	1(2.56)	5.13
Control group	39	4(10.26)	2(5.13)	3(7.69)	23.08
χ2	—	—	—	—	5.185
P	—	—	—	—	0.022

3.3. Immune function indicators

Before treatment, there were no significant differences in the levels of IgG and IgM between the two groups ($P > 0.05$). After treatment, the levels of IgG and IgM in the observation group were significantly lower than those in the control group, with statistically significant differences ($P < 0.05$). Compared with the baseline before treatment in the same group, the levels of IgG and IgM decreased significantly in both groups after treatment ($P < 0.05$). See **Table 4**.

Table 4. Immune function indicators (mean ± SD, g/L)

Group	Case number	IgG		IgM	
		Before treatment	After treatment	Before treatment	After treatment
Observation group	39	11.23 ± 0.56	8.70 ± 0.40	1.77 ± 0 31	1.40 ± 0.29
Control group	39	11.28 ± 0.50	9.34 ± 0.42	1.78 ± 0.28	1.55 ± 0.22
t	—	0.415	6.891	0.149	2.573
P	—	0.678	0.000	0.881	0.012

Note: Compared with baseline before treatment in the same group, $P < 0.05$.

3.4. Clinical efficacy

The total clinical effective rate of the observation group was 92.31%, which was higher than 74. 36% of the control group. The difference was statistically significant ($\chi^2 = 4.523$, $P = 0.033$). See **Table 5**.

Table 5. Clinical efficacy [n(%)]

Group	n	Markedly Effective	Effective	Ineffective	Total Effective Rate (%)
Observation group	39	20 (51.28)	16 (41.03)	3 (7.69)	92.31
Control group	39	15 (38.46)	14 (35.90)	10 (25.64)	74.36
χ2	—	—	—	—	4.523
P	—	—	—	—	0.033

4. Discussion

4.1. Research background and objectives

Dysphagia after stroke can lead to severe complications such as aspiration pneumonia and malnutrition, which adversely affect patients' prognosis and quality of life. The traditional rehabilitation model focuses on the recovery of limb function, with delayed initiation of swallowing intervention and a lack of dynamic adjustment mechanisms. The concept of closed-loop management emphasizes the cyclic optimization of assessment, intervention and monitoring, and has achieved favorable outcomes in the management of chronic diseases. However, its application in the early rehabilitation of post-stroke dysphagia remains insufficient [3]. This study constructed an early rehabilitation protocol based on the closed-loop management of **assessment–intervention–monitoring**, and adopted a randomized controlled trial to verify its effects on patients' nutritional status, immune function, complications and clinical efficacy.

4.2. Result analysis and literature comparison

This study showed that after treatment, the levels of serum total protein, hemoglobin and albumin in the observation group were higher than those in the control group ($P < 0.05$), suggesting that the early rehabilitation protocol based on closed-loop management can significantly improve the nutritional status of patients. The possible reasons are as follows: this protocol improves the efficiency and safety of actual food intake through targeted swallowing muscle training and postural adjustment. Meanwhile, individualized dietary guidance provided by dietitians ensures adequate intake of energy and protein and avoids gastrointestinal intolerance related to nasogastric feeding. These findings are consistent with those reported by Zhang Qiqi, who found that early comprehensive rehabilitation can ameliorate nutritional indicators in patients [4].

This study also found that the total incidence of complications (aspiration, aspiration pneumonia, abdominal distension and diarrhea) in the observation group was significantly lower than that in the control group (5.13% vs. 23.08%, $P = 0.022$). The underlying reasons were analyzed as follows: the continuous monitoring mechanism in closed-loop management can promptly identify the risk of aspiration and implement interventions by adjusting feeding posture

or suspending oral intake. Meanwhile, systematic oropharyngeal rehabilitation training enhances the laryngeal protective reflex and reduces the probability of aspiration.

Shang Na et al. also confirmed that swallowing training combined with rehabilitation exercises can lower the incidence of aspiration pneumonia, which is consistent with the results of the present study [5].

In terms of immune function, the levels of IgG and IgM in the observation group were lower than those in the control group after treatment ($P < 0.05$). Immunological disturbance commonly occurs in post-stroke patients due to stress and malnutrition, and elevated IgG and IgM may reflect a state of chronic inflammation. The lower immunoglobulin levels in the observation group indicated alleviated inflammatory response and gradual normalization of immune function. Dai Yanyan et al. [6] demonstrated that comprehensive rehabilitation could improve immune indicators. The more marked decline of IgG and IgM in the observation group of this study may be attributed to the fact that closed-loop management reduced infectious complications, thereby decreasing persistent activation of the immune system. In terms of clinical efficacy, the total effective rate of the observation group (92.31%) was significantly higher than that of the control group (74.36%, $P = 0.033$), indicating that the closed-loop management protocol could restore swallowing function more effectively. Compared with the effective rate of approximately 85% reported by Liu Ran et al. [7] for comprehensive rehabilitation training, the efficacy in this study was further improved. This may be because the present protocol emphasizes dynamic assessment and timely adjustment, avoiding the plateau stage that may occur with fixed training regimens.

4.3. Conclusions and future research directions

In conclusion, the early rehabilitation protocol based on the **assessment–intervention–monitoring** closed-loop management can significantly improve nutritional status and immune function, reduce the incidence of complications, and enhance clinical efficacy in patients with post-stroke dysphagia. Further multicenter, large-sample studies should be conducted in the future with prolonged follow-up duration to explore the effects of this protocol on patients' long-term quality of life, social rehabilitation rate, and health economic indicators.

4.4. Research value and limitations

This study innovatively integrated the concept of closed-loop management into the early rehabilitation of patients with post-stroke dysphagia and constructed an operable and replicable protocol, which provides evidence-based references for clinical practice. Meanwhile, several limitations of the present study should be acknowledged: it was designed as a single-center trial with a relatively small sample size; the follow-up period was only 4 weeks, and the long-term efficacy remains unclear; moreover, the blinding method was not adopted in outcome evaluation, which may lead to performance bias. Further well-designed studies are required to verify the robustness of the research conclusions.

Disclosure statement

The author declares no conflict of interest.

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