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Effect of Exercise Training Combined with Galantamine on Neurological Function and Muscle Strength Recovery in Patients with Hemiplegia after Acute Ischemic Stroke

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Abstract

Objective: To analyze the effect of exercise training combined with galantamine hydrobromide injection on the neurological and motor function of patients with hemiplegia after acute ischemic stroke. **Methods:** A total of 100 patients with acute ischemic stroke admitted to the Department of Neurology of our hospital from April 2025 to February 2026 were selected as the study subjects. According to the intervention protocol, they were divided into an observation group (50 cases receiving galantamine + conventional treatment + exercise training) and a control group (50 cases receiving conventional treatment + exercise training). General clinical data were collected from both groups, and assessments were performed before and after intervention using the National Institutes of Health Stroke Scale (NIHSS), Modified Rankin Scale (mRS), and Manual Muscle Test (MMT). **Results:** There were no statistically significant differences in gender, age, TOAST classification, or disease course between the observation group and the control group of patients with acute ischemic stroke hemiplegia ($P > 0.05$). Compared between the observation group and the control group, the MMT values were significantly higher after treatment than before, with statistically significant differences ($P < 0.001$), while no statistically significant difference was observed between the two groups ($P > 0.05$). After treatment, the mRS scores and NIHSS scores in both groups decreased significantly compared to pre-treatment levels ($P < 0.001$), with the observation group showing significantly lower scores than the control

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group ($P < 0.001$). No statistically significant difference was observed in upper limb muscle strength efficacy between the two groups ($\chi^2 = 5.93$, $P > 0.05$), whereas a statistically significant difference was noted in lower limb muscle strength efficacy ($\chi^2 = 16.07$, $P < 0.001$). The efficacy rate of the observation group (54.00%) was significantly higher than that of the control group (16.00%). Pairwise comparisons revealed statistically significant differences in the efficacy rates of lower limb muscle strength between the two groups ($P < 0.05$). **Conclusion:** Galantamine combined with exercise training can promote the recovery of neurological function and muscle strength in patients with acute ischemic stroke, improve the ability of daily living activities.

Keywords

Galantamine, Exercise Training, Acute Ischemic Stroke, Neurological Function Recovery, Retrospective Analysis

1. Background

Stroke is an acute cerebrovascular disease caused by sudden rupture or occlusion of cerebral blood vessels, leading to impaired blood flow to the brain and subsequent damage to brain tissue [1]. Among these, acute ischemic stroke (AIS) accounts for approximately 80% of all stroke cases, characterized by rapid onset, high disability rate, and high recurrence rate. Post-onset, insufficient cerebral blood perfusion induces ischemic and hypoxic damage to neurons, leaving about 60% - 70% of surviving patients with varying degrees of motor and cognitive dysfunction, severely affecting their quality of life and imposing a heavy burden on society and families [2]-[4]. Current clinical standard treatments primarily focus on antiplatelet aggregation, platelet stabilization, improvement of cerebral circulation, and neurotrophic support, while comprehensive rehabilitation therapy demonstrates synergistic neuroplasticity effects [5]. Exercise training, as a core rehabilitation approach for AIS, can improve limb motor function by promoting neuroplasticity; however, single exercise training has limited efficacy in patients with moderate to severe neurological deficits [6] [7]. Galantamine, a reversible and highly selective acetylcholinesterase inhibitor, increases synaptic acetylcholine concentration, enhances cholinergic neurotransmission, and improves neurological and cognitive functions [8]-[10]. Recent studies have confirmed the neuroprotective effects of galantamine in the ultra-early stages of AIS, which may involve reducing cytotoxic edema and protecting damaged neural tissues [11].

Previous studies have predominantly focused on the single-intervention effects of galantamine or exercise training, with limited clinical research on their combined application, and their practical efficacy still requires further validation. This study retrospectively analyzed clinical data of AIS patients admitted to our hospital to compare the intervention effects of galantamine combined with exercise training versus single exercise training, providing a practical basis for the clinical

promotion and application of combined intervention protocols.

2. Materials and Methods

2.1. General Data

A retrospective study was conducted on 100 patients with acute ischemic stroke admitted to the Department of Neurology at the Affiliated Hospital of Youjiang Medical University for Nationalities from April 2025 to February 2026, using data from the hospital's electronic medical record system (HIS), imaging information management system (Hinacom), and rehabilitation department medical records. This study was approved by the Ethics Committee of the Affiliated Hospital of Youjiang Medical University for Nationalities, and all patients provided informed consent.

Inclusion criteria: ① Meet the AIS diagnostic criteria in the "China Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke 2023" [1], confirmed as cerebral infarction by cranial CT/MRI examination, and exclude cerebral hemorrhage; ② The onset time is ≤72 hours, vital signs are stable, and there is clear motor dysfunction; ③ Complete clinical data, including general information, imaging examinations, laboratory tests, treatment plans, efficacy evaluation, and follow-up records; ④ Able to cooperate in completing motor training and various assessments; ⑤ The patient or family member signs the informed consent for clinical diagnosis and treatment.

Exclusion criteria: ① Concomitant brain tumors, central nervous system infections, cerebrovascular malformations, or other brain disorders; ② Allergy to galantamine or contraindications to cholinesterase inhibitors; ③ Severe functional failure of vital organs (heart, liver, kidneys, lungs) or coagulation disorders; ④ Mental disorders or cognitive impairments preventing assessment cooperation; ⑤ Incomplete follow-up data, intervention discontinuation, or hospital transfer.

Patients were divided into an observation group and a control group, each consisting of 50 cases, based on whether they received exercise training combined with galantamine hydrobromide injection during hospitalization. The observation group received conventional basic treatment plus galantamine and individualized exercise training, while the control group received conventional basic treatment plus individualized exercise training. Data from both groups were collected as follows: ① General demographic data: gender, age; ② Disease-related data: time to onset, Trial of Org 10172 in Acute Stroke Treatment (TOAST), baseline National Institutes of Health Stroke Scale (NIHSS), Modified Rankin Scale (mRS), and Manual Muscle Test (MMT); ③ Efficacy evaluation data: NIHSS, mRS, MMT before and after treatment.

2.2. Intervention Protocol

Both groups received individualized treatment plans jointly developed by neurologists and rehabilitation physicians, with exercise training conducted under one-

on-one guidance by professional rehabilitation therapists.

2.2.1. Conventional Basic Treatment

Both groups received standard AIS treatment: antiplatelet aggregation (aspirin 100 mg qd or clopidogrel 75 mg qd); statins for lipid-lowering and plaque stabilization (atorvastatin 20 mg qn or rosuvastatin 10 mg qn); cerebral circulation improvement (butylphthalide, edaravone, etc.); neurotrophic support (sodium citicoline, etc.); while controlling risk factors such as blood pressure, blood glucose, and blood lipids, and providing symptomatic supportive therapy.

2.2.2. Individualized Exercise

Training Both groups initiated training within 48 hours after disease stabilization (stable vital signs and no progression of neurological deficits for 48 hours). The intensity should be such that patients experienced mild fatigue without significant pain (VAS score < 3). Training content: Week 1 focused on passive joint mobility training (flexion/extension and rotation of the affected shoulder, elbow, wrist, hip, knee, and ankle joints) and core stability training (bridge exercise). Week 2 gradually introduced active exercises: active resistance training (straight leg raises, shoulder flexion, wall-supported static squats), balance and gait training (transition from seated to standing balance, assisted gait training with crutches/assistive devices). Training was conducted once daily for 40 minutes, 5 days per week, over a 2-week course.

2.2.3. Galantamine Administration

The observation group received intramuscular injection of Galantamine Hydrobromide Injection (Shanghai Xudong Haipu Pharmaceutical Co, Ltd, National Drug Approval Number H31020671,1 mL: 5 mg) in addition to the aforementioned regimen, at a dose of 5 mg per injection, once daily, for a treatment course of 2 weeks.

2.3. Observation Indicators

2.3.1. Clinical Outcomes

Before treatment (admission) and after treatment (discharge): ① NIHSS score (0-42 points): Higher scores indicate more severe neurological deficits; ② mRS score (0 - 6 points): Higher scores indicate more severe neurological impairment; ③ Manual Muscle Test (MMT) assessment, total score 0 - 5 points, lower scores indicate weaker muscle strength and poorer motor function.

2.3.2. Evaluation of Muscle Strength Recovery [12]

A treatment is considered to have demonstrated significant efficacy if the muscle strength grade improves by two or more levels, or if the muscle strength grade is restored to grade V. If the muscle strength grade improves by one level but does not reach grade V, the treatment is deemed effective. If no improvement in muscle strength grade is observed, the treatment is classified as ineffective.

2.4. Statistical Analysis

Data analysis was performed using SPSS 23.0 software. Measurement data conforming to normal distribution were described using ($\overline{x} \pm s$). Between-group comparisons were conducted using the independent samples t-test, while within-group comparisons were performed using the paired t-test. Measurement data non-conforming to normal distribution were expressed as [M (P_{25}, P_{75})], with between-group comparisons using the Mann-Whitney U rank-sum test and within-group comparisons using the Wilcoxon rank-sum test. Categorical data were presented as n (%) and compared between groups using the chi-square test with two-tailed testing at an alpha level of 0.05.

3. Results

3.1. Comparison of General Clinical Data between the Observation Group and the Control Group of Patients with Hemiplegia Due to Acute Ischemic Stroke

No statistically significant differences were observed in gender, age, TOAST classification, disease course between the observation group and the control group of patients with acute ischemic stroke and hemiplegia ($P > 0.05$) (Table 1).

Table 1. Comparison of general data between the observation group and control group of patients with hemiplegia due to acute ischemic stroke.

Metric		Observation group ($n = 50$)	Control group ($n = 50$)	X^2 /t/z	P
Sex [n(%)]	Male	38 (76.0)	29 (58.0)	3.66	0.06
	Female	12 (24.0)	21 (42.0)		
Age [years/($\overline{x} \pm s$)]		63 ± 11	61 ± 9	−1.46	0.15
TOAST typing [n (%)]	Atherosclerotic type of large arteries	41 (82.0)	33 (66.0)	3.33	0.07
	Arteriole occlusive type	9 (18.0)	17 (34.0)		
Course of disease [h/M (P_{25}, P_{75})]		14.50 (7.00, 24.00)	16.00 (6.00, 24.00)	−0.01	0.99

Note: The observation group received conventional basic treatment plus galantamine and individualized exercise training, while the control group received conventional basic treatment plus individualized exercise training.

3.2. Comparison of MMT, mRS, and NIHSS Scores before and after Treatment in Patients with Acute Ischemic Stroke Hemiplegia in the Observation Group and Control Group

Compared between the observation group and the control group, the MMT values were significantly higher after treatment than before, with statistically significant differences ($P < 0.001$). No statistically significant difference was observed in MMT between the two groups ($P > 0.05$) (Table 2).

After treatment, both the observation group and control group showed statistically significant decreases in mRS and NIHSS scores compared to pre-treatment levels ($P < 0.001$). Notably, the mRS and NIHSS scores in the observation group

were significantly lower than those in the control group, with a statistically significant difference ($P < 0.001$) (Table 3).

Table 2. Comparison of MMT before and after treatment between the two groups of patients [$M(P_{25}, P_{75})$].

Group	Upper limb muscle strength				Lower limb muscle strength			
	Before intervention	After the intervention	z	P	Before intervention	After the intervention	z	P
Observation group	3.00 (2.00, 3.25)	4.00 (3.00, 5.00)	−5.836	<0.001	3.00 (2.00, 4.00)	4.00 (3.00, 5.00)	−5.679	<0.001
Control group	3.00 (2.00, 4.00)	4.00 (3.00, 4.00)	−5.129	<0.001	3.00 (2.75, 4.00)	4.00 (3.00, 4.00)	−5.523	<0.001
z	−1.172				−1.719			
P	0.241				0.086			

Table 3. Comparison of mRS scores and NIHSS scores before and after treatment between the two groups [$M(P_{25}, P_{75})$].

Group	mRS grade				NIHSS grade			
	Before intervention	After the intervention	z	P	Before intervention	After the intervention	z	P
Observation group	4.00 (4.00, 4.00)	2.00 (1.00, 3.25)	−5.778	<0.001	7.00 (5.00, 9.25)	2.00 (1.00, 4.25)	−6.109	<0.001
Control group	4.00 (4.00, 4.00)	3.00 (2.00, 4.00)	−5.282	<0.001	5.00 (4.00, 9.00)	3.50 (2.00, 6.00)	−5.825	<0.001
z	−3.63				−3.94			
P	<0.001				<0.001			

Note: NIHSS is the National Institutes of Health Stroke Scale, and mRS is the Modified Rankin Scale (mRS).

3.3. Comparison of Clinical Efficacy between the Observation Group and the Control Group in Patients with Acute Ischemic Stroke and Hemiplegia

In the observation group, the rates of significant improvement, effective, and ineffective upper limb muscle strength were 26 cases (52.00%), 17 cases (34.00%), and 7 cases (14.00%), respectively. In the control group, the rates were 16 cases (32.00%), 18 cases (36.00%), and 16 cases (32.00%), respectively. There was no statistically significant difference in the efficacy of upper limb muscle strength between the observation group and the control group ($\chi^2 = 5.93$, $P > 0.05$). However, there was a statistically significant difference in the efficacy of lower limb muscle strength between the two groups ($\chi^2 = 16.07$, $P < 0.001$). The rate of significant improvement in the observation group (54.00%) was higher than that in the control group (16.00%). Pairwise comparisons revealed statistically significant differences in the rates of significant improvement, effective, and ineffective efficacy between the two groups ($P < 0.05$) (Table 4).

Table 4. Comparison of muscle strength efficacy between the two groups [*n* (%)].

Group	Upper limb muscle strength efficacy			Lower limb muscle strength efficacy		
	Excellence	Valid	of no avail	Excellence	Valid	of no avail
Observation group	26 (52.00)	17 (34.00)	7 (14.00)	27 (54.00)	14 (28.00)	9 (18.00)
Control group	16 (32.00)	18 (36.00)	16 (32.00)	8 (16.00)	28 (56.00)	14 (28.00)
Statistics		5.93			16.07	
P		>0.05			<0.001	

4. Discussion

The pathophysiological mechanism of acute ischemic stroke involves ischemic-hypoxic damage to neurons caused by insufficient cerebral blood flow perfusion. In the infarct core region, neurons undergo rapid irreversible necrosis, while those in the ischemic penumbra remain in a state of reversible injury. The core clinical treatment objectives are to promptly salvage the ischemic penumbra, mitigate neuronal damage, promote neurological function recovery, and reduce disability rates [13] [14]. The cholinergic system participates in the complex pathophysiological processes following ischemic stroke, playing a critical role in secondary neuronal damage during both the acute and chronic phases of brain injury. Additionally, the cholinergic system in neurons is essential for regulating cognitive functions, sensory perception, and motor control [15] [16]. Our study demonstrated that the observation group achieved significantly lower NIHSS and mRS scores compared to the control group post-treatment, with superior recovery of lower limb muscle strength on the hemiplegic side. This suggests that galantamine and exercise training exhibit a significant synergistic intervention effect, with combined application yielding better outcomes than exercise training alone. However, no significant improvement was observed in upper limb muscle strength. Post-stroke hemiplegic patients exhibit slower recovery of upper limb function, with approximately half of the patients still experiencing upper limb motor dysfunction years after onset. These findings align with the clinical patterns and underlying mechanisms of upper limb recovery in stroke hemiplegia [17] [18].

This study, based on clinical diagnostic and therapeutic data, retrospectively analyzed that galantamine combined with exercise training can enhance the short-term intervention effects in patients with acute ischemic stroke (AIS), demonstrating a synergistic mechanism that promotes neurological function and muscle strength recovery on the hemiplegic side, consistent with previous research findings [8] [11] [19]. The two interventions may exert a cumulative effect through multiple pathways: On one hand, as a highly selective acetylcholinesterase inhibitor, galantamine specifically inhibits acetylcholinesterase activity, increasing acetylcholine concentration in the synaptic cleft of the ischemic area, improving cholinergic pathway signaling, reducing neurotoxic edema, maintaining the integrity of the corticospinal tract, and activating cholinergic receptors to promote the synthesis and release of neurotrophic factors in the brain, thereby laying the

foundation for neural repair [20] [21]. On the other hand, exercise training reduces the volume of cerebral infarction, attenuates the expression of apoptosis factors, and increases the expression of growth factors, maximizing the compensatory capacity of the perilesional cortex and promoting cerebral metabolism, thereby restoring neurological and motor functions and shortening rehabilitation time [22] [23]. When combined, galantamine enhances the neuroplasticity-promoting effects of exercise training, while exercise training amplifies the neuroprotective effects of galantamine, more effectively salvaging ischemic penumbra neurons.

This study still has certain limitations: it is a single-center retrospective study with a limited sample size, and the generalizability of the results requires further validation through multicenter, large-sample studies. Only the short-term efficacy of the intervention was assessed, without long-term follow-up, making it impossible to determine the impact of the combined regimen on long-term patient outcomes. Future research could involve multicenter, large-sample prospective controlled studies with extended follow-up to provide more robust evidence for developing individualized clinical strategies.

5. Conclusion

In conclusion, the combination of galantamine and exercise training in patients with hemiplegia due to acute ischemic stroke can reduce the degree of neurological deficits and promote muscle strength recovery. Moreover, the two interventions exhibit a synergistic effect, demonstrating superior efficacy compared to exercise training alone. This combined approach provides a novel and effective option for the comprehensive clinical management of acute ischemic stroke, offering significant value for clinical application and promotion.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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