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A Study on the Application of Remote Ischemic Postconditioning Training in Patients after Mechanical Thrombectomy for Acute Ischemic Stroke

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Abstract: *Objective*: This study examines the impact of remote ischemia post-conditioning (RIPostC) on clinical outcomes in patients who have undergone mechanical thrombectomy for acute ischemic stroke (AIS), with the aim of guiding improvements in patient outcomes. *Methods*: We selected 78 patients with acute ischemic stroke (AIS) who underwent mechanical thrombectomy in the Neurointensive Care Unit (NICU) of our hospital from January to December 2024 as study subjects. Patients were randomly assigned to either the experimental group or the control group using a random number table. All patients received identical standard general treatment, routine post-mechanical thrombectomy therapy, and nursing care. The experimental group additionally received remote ischemic postconditioning (RIPostC) treatment for 7 consecutive days, twice daily, with 5 cycles per session. An ischemic adaptation training device was used to alternately inflate and deflate both upper limbs for 5 minutes per session. The total training duration was 7 days. For the experimental group, the inflation pressure was set at 200 mmHg, and one complete RIPostC session was defined as five cycles (45 minutes). The control group received sham RIPostC treatment for 7 days. In the control group, the inflation pressure was set at 60 mmHg, which induced a sensation of limb constriction while maintaining palpable radial and brachial artery pulses. One complete sham session was also defined as five cycles (45 minutes). Both groups completed a total of 14 RIPostC/sham sessions. Evaluations were performed before the intervention, at 3 days and 7 days after the intervention, assessing NIHSS scores, modified Rankin Scale (mRS) scores, and laboratory markers (PCT, CRP, IL-6). Additional assessments of NIHSS and mRS scores were conducted before discharge and at the 90-day follow-up. Transcranial Doppler ultrasound (TCD) was used to evaluate blood flow velocity in the affected cerebral vessels, including peak systolic velocity (Vs), diastolic velocity (Vd), mean velocity (Vm), and pulsatility index (PI). *Results*: Of the 78 enrolled patients, 62 completed the study, including 32 in the experimental group and 30 in the control group. There were no statistically significant differences between the two groups in baseline characteristics such as gender, age, history of smoking and alcohol consumption, and past medical history ($p > 0.05$), indicating

comparability. Seven days after intervention, the experimental group demonstrated significantly better outcomes than the control group in Vd, Vm, PI, mRS scores, NIHSS scores, PCT levels, and IL-6 levels (all $p < 0.05$). Similarly, at 3 days, 7 days, pre-discharge, and during the 90-day follow-up assessments, the experimental group showed consistently superior mRS and NIHSS scores compared to the control group (all $p < 0.05$). Repeated measures ANOVA indicated significant interaction effects between time and group for Vs, Vd, Vm, PI, mRS scores, NIHSS scores, CRP, and IL-6 (all $p < 0.05$). Notably, there were significant main effects of both time and group on mRS and NIHSS scores ($p < 0.05$), as well as significant main effects of time on Vs, Vd, Vm, PI, CRP, PCT, and IL-6 ($p < 0.05$). A total of 19 patients experienced adverse reactions in this study, including 15 in the experimental group and 4 in the control group. While the incidence of skin petechiae, dizziness, palpitations, and chest tightness showed no significant between-group differences ($p > 0.05$), the experimental group had a significantly higher incidence of skin ecchymosis and overall adverse event rate compared to the control group (both $p < 0.05$). All adverse reactions resolved after symptomatic treatment, and no serious adverse events occurred. *Conclusion*: RIPostC training can reduce the inflammatory response in patients with acute ischemic stroke (AIS) and improve cerebral blood flow perfusion in the affected area, and promote neurological recovery.

Keywords: Acute ischemic stroke (AIS); Mechanical thrombectomy; Remote ischemic Postconditioning (RIPostC); Neurological recovery; Hemodynamics; Inflammatory factors

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1. Introduction

Acute ischemic stroke (AIS) is a common cerebrovascular disease encountered in clinical practice, predominantly affecting middle-aged and elderly populations. Acute ischemic stroke with large vessel occlusion (AIS-LVO) typically involves major blood vessels including the internal carotid artery, middle cerebral artery, and vertebrobasilar artery. It is characterized by sudden onset, critical clinical manifestations, rapid disease progression, and poor prognosis [1,2]. Mechanical thrombectomy is the primary therapeutic strategy adopted for such patients in clinical settings [3]. Mechanical thrombectomy can rapidly recanalize occluded vessels and restore cerebral blood perfusion, yielding substantial clinical benefits for patients [4]. However, restricted by the brain tissue's low tolerance to ischemia and cerebral ischemia-reperfusion injury (CIRI), unsatisfactory prognoses are observed in a subset of patients [5]. Remote ischemic postconditioning (RIPostC) refers to transient and repeated occlusion and restoration of blood flow to a single tissue or organ, which activates the body's endogenous anti-ischemic injury defense system. This mechanism enhances the tolerance of distant vital organs and tissues to ischemic damage, alleviates CIRI, and exerts neuroprotective effects on the brain [6]. Featuring simplicity, safety, and non-invasiveness, RIPostC is a technique convenient for clinical implementation and widespread promotion [7]. On this basis, the present study aims to investigate the impact of RIPostC on the clinical prognosis of patients with AIS following mechanical thrombectomy, so as to provide evidence-based references for optimizing patient prognosis.

2. Subjects and methods

2.1. Study subjects

Patients with AIS who underwent mechanical thrombectomy in the Neurological Intensive Care Unit of our

hospital from January to December 2024 were enrolled as study subjects. This study was approved by the Medical Ethics Committee of our hospital (Approval No. 2025KY107).

2.1.1. Inclusion criteria

(1) Consistent with the diagnostic criteria for AIS specified in the latest domestic Chinese guidelines, and confirmed as AIS via cranial CT or MRI examination [8];
(2) Aged ≥ 18 years old;
(3) National Institutes of Health Stroke Scale (NIHSS) score ≥ 6 on admission, accompanied by obvious neurological deficit symptoms;
(4) Received mechanical thrombectomy;
(5) Written informed consent obtained from patients or their family members;
(6) Complete clinical data available.

2.1.2. Exclusion criteria

(1) Unstable vital signs, or failure of vital organs including the heart, liver, kidney and lung;
(2) Combined systemic infection, hematological diseases, autoimmune diseases, metabolic diseases or malignant tumors;
(3) Bilateral upper limb trauma, thrombotic disorders, asymmetric bilateral upper limb blood pressure, or weakened/absent radial artery pulse;
(4) Obvious bleeding tendency, or severe hypertension uncontrollable by medications;
(5) Participation in other ongoing clinical trials.

2.2. Study methods

This study adopted a randomized, placebo-controlled trial design. Patients were divided into an experimental group and a control group by the random number table method.

All patients in both groups received identical basic treatment as well as routine treatment and nursing care after mechanical thrombectomy, including a low-salt and low-fat diet, smoking and alcohol cessation, blood pressure, lipid, and blood glucose management; standardized administration of antiplatelet agents, neuroprotective drugs, statins and other medications; specialized nursing such as dynamic condition monitoring, prevention of postoperative complications and early rehabilitation guidance. On the basis of the above basic treatment and nursing, the experimental group received bilateral upper limb RIPostC training using a dedicated remote ischemic conditioning training device. The training protocol consisted of 5 cycles per session. Each cycle comprised 5 minutes of cuff inflation and compression followed by 5 minutes of deflation and decompression. The intervention was performed twice daily for 7 consecutive days, with an inflation pressure set at 200 mmHg, and the total duration of each training session was 45 minutes. All procedures were carried out by specialized nurses who received unified training and passed standardized assessments in strict accordance with standard operating procedures. The control group underwent sham RIPostC training alongside the same basic treatment and nursing. The training device, operating duration, number of cycles, and performing nurses were identical to those used in the experimental group. Only the inflation pressure was adjusted to 60 mmHg to create a mild limb constriction sensation, thereby eliminating the confounding psychological suggestion effect on study outcomes.

2.3. Outcome assessment tools

2.3.1. Cerebral hemodynamic indicators

Transcranial Doppler ultrasound (TCD) was applied to monitor cerebral hemodynamic parameters of the lesioned-side cerebral vessels with a 2-MHz handheld transducer. Measured indicators included peak systolic velocity (Vs), end-diastolic velocity (Vd), mean flow velocity (Vm), and pulsatility index (PI). Assessments were conducted before intervention, 3 days and 7 days after intervention, respectively.

2.3.2. Assessment of neurological function-related indicators

(1) National Institutes of Health Stroke Scale (NIHSS)

The severity of neurological deficits was evaluated across 15 dimensions including level of consciousness, gaze, visual fields, facial palsy, limb motor function, ataxia, sensation, language, and others. The total score ranges from 0 to 42, with higher scores indicating more severe neurological deficits [9,10]. Evaluations were performed before intervention, 3 days and 7 days post-intervention, before hospital discharge, and at the 90-day follow-up.

(2) Modified Rankin Scale (mRS)

Functional disability was assessed in terms of activities of daily living and severity of functional impairment [11]. The total score ranges from 0 to 6, and higher scores correspond to poorer neurological functional prognosis. Assessments were implemented at the same time points as the NIHSS evaluation.

2.3.3. Levels of inflammatory factors

Enzyme-linked immunosorbent assay (ELISA) was used to detect serum inflammatory factors, namely C-reactive protein (CRP), procalcitonin (PCT), and interleukin-6 (IL-6). Blood samples were collected for detection before intervention, 3 days and 7 days after intervention.

2.3.4. Adverse reaction monitoring

All adverse events occurring in both groups were fully documented throughout the trial, including skin petechiae, ecchymosis, dizziness, palpitations, chest tightness, and other manifestations, to evaluate the clinical safety of RIPostC training.

2.4. Statistical methods

Statistical analyses were performed using IBM SPSS 26.0 software. Measurement data conforming to a normal distribution were expressed as mean ± standard deviation; intergroup comparisons were conducted via independent samples *t*-test, and intragroup comparisons across multiple time points were analyzed by repeated measures analysis of variance (ANOVA). Mauchly's test of sphericity was applied, and the Greenhouse-Geisser correction was adopted when the sphericity assumption was violated. Enumeration data were presented as cases (percentage) [n(%)], and intergroup comparisons were performed using the Chi-square test. A *p-value* less than 0.05 was considered to indicate a statistically significant difference.

3. Results

3.1. Comparison of baseline data between the two groups

A total of 78 patients were initially enrolled in this study. Among them, 4 presented unstable hemodynamics, 1 suffered from severe pulmonary infection, 3 could not tolerate the training intervention, 5 withdrew

from the trial midway, and 3 were lost to follow-up. Finally, 62 patients completed the study, including 32 patients in the experimental group and 30 patients in the control group. In the experimental group, there were 20 males (62.50%) and 12 females (37.50%), with ages ranging from 45 to 82 years and a mean age of (65.41±11.85) years. Thirteen patients (40.63%) had a smoking history, and 11 (34.38%) had a drinking history. Twenty-one patients (65.63%) were complicated with hypertension, 5 (15.63%) with diabetes mellitus, 10 (31.25%) with heart disease, and 12 (37.50%) with a history of cerebrovascular disease. The control group contained 30 patients: 16 males (53.33%) and 14 females (46.67%), aged 43 to 80 years with a mean age of (67.27 ± 10.40) years. Seven patients (23.33%) had a smoking history, and 9 (30.00%) had a drinking history. Twenty-two patients (73.33%) had hypertension, 9 (30.00%) had diabetes mellitus, 9 (30.00%) had heart disease, and 10 (33.33%) had a history of cerebrovascular disease. No statistically significant differences were observed between the two groups in baseline data, including gender, age, history of smoking and alcohol consumption, and past medical history ($p > 0.05$) (see **Table 1**).

Table 1. Comparison of baseline data between the two groups

Group	Number of cases	Male	Female	Age	Smoking history	Drinking history	Hypertension history	Diabetes history	Heart disease history	Cerebrovascular disease history
Experimental group	32	20 (62.50)	12 (37.50)	65.41 ± 11.85	13 (40.63)	11 (34.38)	21 (65.63)	5 (15.63)	10 (31.25)	12 (37.50)
Control group	30	16 (53.33)	14 (46.67)	67.27 ± 10.40	7 (23.33)	9 (30.00)	22 (73.33)	9 (30.00)	9 (30.00)	10 (33.33)
χ^2/t value		0.534		-0.655	2.119	0.136	0.433	1.830	0.011	0.117
p value		0.465		0.515	0.146	0.713	0.511	0.176	0.915	0.732

3.2. Comparison of clinical observation indicators between the two groups before and after intervention

At 7 days after intervention, the experimental group exhibited superior levels of Vd, Vm, PI, mRS score, NIHSS score, PCT, and IL-6 compared with the control group, with statistically significant differences ($p < 0.05$). At 3 days and 7 days post-intervention, before discharge, and at follow-up, the mRS and NIHSS scores of the experimental group were significantly better than those of the control group ($p < 0.05$) (see **Table 2**). Results of repeated measures analysis of variance showed significant time-group interaction effects on Vs, Vd, Vm, PI, mRS score, NIHSS score, CRP and IL-6 ($p < 0.05$). Significant main effects of time and group were detected for mRS score and NIHSS score ($p < 0.05$), while time exerted significant main effects on Vs, Vd, Vm, PI, CRP, PCT and IL-6 ($p < 0.05$) (see **Tables 2–3**).

Table 2. Comparison of indicators at each time point after intervention between the two groups ($\overline{x} \pm s$)

Group	Vs (cm/s)			Vd (cm/s)			Vm (cm/s)			PI		
	Before intervention	3 days after intervention	7 days after intervention	Before intervention	3 days after intervention	7 days after intervention	Before intervention	3 days after intervention	7 days after intervention	Before intervention	3 days after intervention	7 days after intervention
Experimental group	97.63 ± 16.95	88.41 ± 15.21	79.91 ± 13.56	43.31 ± 15.56	35.63 ± 13.67	28.19 ± 12.08	61.42 ± 15.34	53.22 ± 13.58	45.43 ± 11.64	0.94 ± 0.31	1.05 ± 0.31	1.21 ± 0.34

Control group	97.07 ± 18.35	93.27 ± 18.80	87.57 ± 20.09	43.20 ± 15.72	40.27 ± 14.73	37.73 ± 13.46	61.16 ± 14.98	57.93 ± 14.63	54.34 ± 13.99	0.94 ± 0.38	0.98 ± 0.37	0.97 ± 0.38
t value	0.125	-1.122	-1.748	0.028	-1.287	-2.942	0.068	-1.316	-2.735	-0.004	0.908	2.598
p value	0.901	0.266	0.086	0.978	0.203	0.005**	0.946	0.193	0.008**	0.997	0.368	0.012*
F value	$F_{Interaction} = 13.305$, $F_{Between-group} = 0.868$, $F_{Time} = 141.236$			$F_{Interaction} = 42.113$, $F_{Between-group} = 1.728$, $F_{Time} = 191.472$			$F_{Interaction} = 48.136$, $F_{Between-group} = 1.591$, $F_{Time} = 296.359$			$F_{Interaction} = 18.842$, $F_{Between-group} = 1.518$, $F_{Time} = 25.463$		
p value	$p_{Interaction} < 0.001$**, $p_{Between-group} = 0.355$, $p_{Time} < 0.001$**			$p_{Interaction} < 0.001$**, $p_{Between-group} = 0.194$, $p_{Time} < 0.001$**			$p_{Interaction} < 0.001$**, $p_{Between-group} = 0.212$, $p_{Time} < 0.001$**			$p_{Interaction} < 0.001$**, $p_{Between-group} = 0.223$, $p_{Time} < 0.001$**		

Group	mRS score					NIHSS score				
	Before intervention	3 days after intervention	7 days after intervention	Before discharge	Follow-up	Before intervention	3 days after intervention	7 days after intervention	Before discharge	Follow-up
Experimental group	4.09 ± 1.00	3.38 ± 1.29	2.94 ± 1.44	2.72 ± 1.46	1.75 ± 1.39	19.19 ± 6.39	14.34 ± 7.11	9.78 ± 6.27	6.84 ± 4.85	3.94 ± 3.45
Control group	4.17 ± 0.79	4.10 ± 0.71	3.83 ± 0.95	3.53 ± 1.01	2.80 ± 0.96	20.87 ± 7.19	17.90 ± 7.27	15.87 ± 7.21	13.13 ± 5.74	9.53 ± 5.66
t value	-0.32	-2.764	-2.915	-2.565	-3.475	-0.973	-1.946	-3.553	-4.669	-4.665
p value	0.75	0.008**	0.005**	0.013*	0.001**	0.334	0.056	0.001**	< 0.001**	< 0.001**
F value	$F_{Interaction} = 21.098$, $F_{Between-group} = 17.188$, $F_{Time} = 35.394$					$F_{Between-group} = 7.419$, $F_{Between-group} = 8.721$, $F_{Time} = 227.671$				
p value	$p_{Interaction} < 0.001$**, $p_{Between-group} < 0.001$**, $p_{Time} < 0.001$**					$p_{Between-group} = 0.001$**, $p_{Between-group} = 0.004$**, $p_{Time} < 0.001$**				

Group	CRP (mg/L)			Procalcitonin (PCT) (ng/mL)			IL-6 (pg/L)		
	Before intervention	3 days after intervention	7 days after intervention	Before intervention	3 days after intervention	7 days after intervention	Before intervention	3 days after intervention	7 days after intervention
Experimental group	56.46 ± 36.46	43.54 ± 30.16	29.84 ± 25.50	0.70 ± 0.64	0.29 ± 0.39	0.09 ± 0.10	25.71 ± 17.97	16.52 ± 13.30	8.09 ± 8.06
Control group	54.52 ± 30.53	47.82 ± 29.83	39.60 ± 27.03	0.71 ± 0.52	0.42 ± 0.38	0.27 ± 0.35	25.20 ± 16.49	21.18 ± 15.61	16.51 ± 14.14
t value	0.227	-0.562	-1.463	-0.043	-1.306	-2.809	0.117	-1.269	-2.903
p value	0.821	0.576	0.149	0.966	0.197	0.008**	0.907	0.209	0.005**
F value	$F_{Between-group} = 7.580$, $F_{Between-group} = 0.292$, $F_{Time} = 95.456$			$F_{Interaction} = 1.544$, $F_{Between-group} = 1.349$, $F_{Time} = 53.157$			$F_{Interaction} = 10.498$, $F_{Between-group} = 1.411$, $F_{Time} = 90.289$		
p value	$p_{Interaction} = 0.004$**, $p_{Between-group} = 0.591$, $p_{Time} < 0.001$**			$p_{Interaction} = 0.222$, $_{Between-group} = 0.250$, $p_{Time} < 0.001$**			$p_{Interaction} = 0.001$**, $p_{Between-group} = 0.240$, $p_{Time} = 0.001$**		

Notes: Vs: peak systolic velocity; Vd: end-diastolic velocity; Vm: mean flow velocity; PI: pulsatility index; CRP: C-reactive protein; PCT: procalcitonin; IL-6: interleukin-6; *$p < 0.05$ **$p < 0.01$

Table 3. Comparison of differences at each time point between the two groups

Group	Vs (cm/s)			Vd (cm/s)			Vm (cm/s)			PI		
	0–3d	**3d–7d**	**0–7d**	**0–3d**	**3d-7d**	**0–7d**	**0–3d**	**3d–7d**	**0–7d**	**0–3d**	**3d–7d**	**0–7d**
Experimental group	9.22 ± 3.59	8.50 ± 3.58	17.72 ± 7.03	7.69 ± 3.44	7.44 ± 4.37	15.13 ± 7.26	8.20 ± 2.54	7.79 ± 3.59	15.99 ± 5.86	-0.11 ± 0.11	-0.15 ± 0.16	-0.26 ± 0.24
Control group	3.80 ± 1.71	5.70 ± 8.94	9.50 ± 9.43	2.93 ± 1.80	2.53 ± 1.87	5.47 ± 3.20	3.22 ± 1.18	3.59 ± 3.37	6.81 ± 3.76	-0.03 ± 0.05	0.01 ± 0.15	-0.02 ± 0.16
t value	7.662	1.637	3.907	6.878	5.807	6.846	9.985	4.745	7.384	-3.776	-4.147	-4.602
p value	< 0.001**	0.107	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**

Group	mRS score				NIHSS score			
	0–3d	3d–7d	7d to follow-up	0–90d	0–3d	3d–7d	7d to follow-up	0–90d
Experimental group	0.72 ± 0.73	0.44 ± 0.67	1.19 ± 1.09	2.34 ± 1.15	4.84 ± 3.57	4.56 ± 4.21	5.84 ± 3.82	15.25 ± 5.05
Control group	0.07 ± 0.58	0.27 ± 0.45	1.03 ± 0.72	1.37 ± 0.85	2.97 ± 3.39	2.03 ± 1.56	6.33 ± 5.41	11.33 ± 6.77
t value	3.901	1.187	0.661	3.777	2.122	3.172	-0.414	2.594
p value	< 0.001**	0.241	0.511	< 0.001**	0.038*	0.003**	0.681	0.012*

Group	CRP (mg/L)			PCT (ng/mL)			IL-6 (pg/mL)		
	0–3d	**3d–7d**	**0–7d**	**0–3d**	**3d–7d**	**0–7d**	**0–3d**	**3d–7d**	**0–7d**
Experimental group	12.92 ± 11.18	13.70 ± 11.42	26.62 ± 18.85	0.41 ± 0.49	0.20 ± 0.36	0.61 ± 0.63	9.19 ± 6.71	8.43 ± 9.12	17.62 ± 13.07
Control group	6.70 ± 7.78	8.22 ± 6.14	14.92 ± 10.89	0.29 ± 0.28	0.15 ± 0.14	0.43 ± 0.32	4.02 ± 2.95	4.67 ± 3.44	8.69 ± 5.32
t value	2.53	2.372	3.016	1.209	0.811	1.408	3.973	2.17	3.566
p value	0.014*	0.022*	0.004**	0.233	0.422	0.166	< 0.001**	0.036*	0.001**

Notes: Vs: peak systolic velocity; Vd: end-diastolic velocity; Vm: mean flow velocity; PI: pulsatility index; CRP: C-reactive protein; PCT: procalcitonin; IL-6: interleukin-6; * $p < 0.05$ ** $p < 0.01$

3.3. Safety analysis

A total of 19 patients developed mild to moderate adverse reactions during the study, and no serious adverse events were observed. Among the 32 patients in the experimental group, 15 (46.88%) presented adverse reactions, including 10 cases of skin petechiae, 11 cases of skin ecchymosis, 3 cases of dizziness, 4 cases of palpitations, and 2 cases of chest tightness. In the control group with 30 patients, 4 cases (13.33%) had adverse reactions, consisting of 3 cases of skin petechiae, 2 cases of dizziness, 2 cases of palpitations, and 1 case of chest tightness. There were no statistically significant between-group differences in the incidence rates of skin petechiae, dizziness, palpitations, and chest tightness ($p > 0.05$). The experimental group showed significantly higher incidence rates of skin ecchymosis and total adverse reactions compared with the control group ($p < 0.05$) (see **Table 4**). All adverse reactions were relieved gradually within 72 hours after intervention. Skin petechiae and ecchymosis resolved spontaneously, while symptoms such as dizziness, palpitations, and chest tightness disappeared after temporary suspension of training and short rest. All patients completed the whole intervention course.

Table 4. Comparison of adverse reactions between the two groups [n(%)]

Group	Number of cases	Skin petechiae	Skin ecchymosis	Skin breakdown	Dizziness	Palpitations	Chest tightness	Total
Experimental group	32	10 (31.25)	11 (34.37)	0	3 (9.38)	4 (12.50)	2 (6.25)	15 (46.88)
Control group	30	3 (10.00)	0 (0.00)	0	2 (6.67)	2（6.67）	1 (3.33)	4 (13.33)
χ^2 *value*		3.034	10.292		< 0.001	0.120	< 0.001	8.196
p value		0.082	0.001		1.000	0.729	1.000	0.004

4. Discussion

Acute ischemic stroke (AIS) is characterized by high incidence, high recurrence, high disability and high mortality rates, and constitutes a leading global cause of disability and death [12]. Its incidence rises sharply with advancing age. Among all subtypes, acute ischemic stroke with large vessel occlusion (AIS-LVO) stands out for its abrupt onset and rapid disease progression, rendering it one of the primary contributors to mortality and disability related to cerebrovascular diseases [13]. The aging population is expected to trigger a dramatic surge in the number of AIS patients in the future [14]. Furthermore, therapeutic efficacy and long-term prognosis of AIS are correlated with multiple factors, including time from symptom onset to hospital arrival, family economic status, health awareness of family caregivers, and the diagnostic and therapeutic capacity of admitting medical institutions [15]. Mechanical thrombectomy remains the first-line clinical therapy beyond pharmacotherapy for patients with AIS-LVO. It enables rapid recanalization of occluded vessels, restores cerebral perfusion, and reduces long-term disability in patients aged over 80 years [13]. Nevertheless, cerebral ischemia-reperfusion injury (CIRI) is a critical factor restricting postoperative neurological functional recovery. Compared with other organs and tissues, the brain exhibits far higher vulnerability to ischemia and hypoxia; neurons within the ischemic core undergo irreversible death within minutes after hypoperfusion onset [16].

Remote ischemic postconditioning (RIPostC) is a noninvasive intervention technique relying on the body's endogenous protective mechanisms. Brief and repeated limb ischemia-reperfusion stimuli activate endogenous anti-ischemic injury signaling pathways and trigger the release of endogenous protective factors, thereby alleviating cerebral ischemia-reperfusion injury (CIRI) in distant vital organs and tissues [16]. Owing to its simple operation and noninvasive nature, this technique has been increasingly applied in the treatment of ischemic diseases [17–19].

The present study demonstrated that RIPostC training administered to AIS patients receiving mechanical thrombectomy could significantly improve hemodynamic indicators of lesioned cerebral vessels. From baseline to day 3 post-intervention, Vd, Vm, and PI were all improved in the experimental group compared with the control group ($p < 0.05$), indicating that RIPostC intervention ameliorates cerebral hemodynamics and alleviates cerebral tissue ischemia and hypoxia. Its underlying mechanism may involve limb ischemic stimulation triggering endogenous protective factors such as nitric oxide and adenosine, which dilate cerebral vessels, improve vascular endothelial function, and relieve cerebral vasospasm, ultimately restoring the balance of cerebral hemodynamics. Existing research has reported that during cerebral ischemia, intracellular ATP production shifts predominantly to anaerobic metabolism, accompanied by reduced intracellular pH, activation of calcium-dependent enzymes, and calcium overload [20,21]. Energy generated

from anaerobic glycolysis is insufficient to sustain the function of membrane ion pumps, stabilize pH and calcium homeostasis, and maintain antioxidant capacity, which consequently induces cell membrane injury [22]. Irreversible cellular apoptosis occurs if blood flow cannot be restored promptly. RIPostC stimulates the immune system to release endogenous protective factors including adenosine and bradykinin, which activate cell membrane and intracellular receptors and subsequently open mitochondrial ATP-sensitive potassium channels to modulate oxygen free radical production [21,23]. Such effects counteract tissue damage caused by ischemia and hypoxia, induce ischemic tolerance in target tissues, preserve endogenous neurological function, mitigate ischemia-reperfusion injury, and reduce cerebral tissue damage [22].

Neurological functional recovery serves as the core indicator for evaluating long-term prognosis in patients with AIS. In the present study, the National Institutes of Health Stroke Scale (NIHSS) and modified Rankin Scale (mRS) scores at all time points were markedly lower in the experimental group than those in the control group ($p < 0.05$). Significant time-group interaction effects confirmed the therapeutic efficacy of the intervention ($p < 0.05$), demonstrating that RIPostC training effectively facilitates early neurological recovery and exerts favorable regulatory effects on long-term functional outcomes among AIS patients treated with mechanical thrombectomy. These findings suggest that RIPostC can improve histological characteristics of cerebral vessels and strengthen endogenous antioxidant defense capacity against cerebral ischemia-reperfusion injury (CIRI) in brain parenchymal cells [24]. Repeated limb ischemia-reperfusion stimulation induced by RIPostC promotes angiogenesis within the ischemic penumbra and exerts neuroprotective effects on peripheral viable neurons [25].

In addition, serum levels of inflammatory factors including CRP, PCT, and IL-6 were significantly lower in the experimental group than in the control group after intervention ($p < 0.05$), indicating that RIPostC could effectively suppress excessive systemic inflammatory response. Inflammatory response is a key pathophysiological link in cerebral ischemia-reperfusion injury. Overactivated inflammation exacerbates secondary brain tissue damage; therefore, inhibiting the release of inflammatory factors and alleviating inflammatory response builds a favorable microenvironment for neurological functional repair [26]. Previous studies have demonstrated that severe cerebral vascular stenosis leads to cerebral ischemia and hypoxia, suppresses neuronal protein synthesis, and stimulates the secretion of inflammatory mediators such as IL-6 [27]. IL-6 can induce T lymphocyte proliferation and further amplify inflammatory reactions. CRP is synthesized by hepatocytes and rises sharply in the presence of infection or tissue injury [28,29]. RIPostC intervention reduces peripheral blood inflammatory factor concentrations and improves clinical prognosis in stroke patients [30].

In terms of clinical safety, the adverse reactions associated with RIPostC training observed in this study were predominantly mild-to-moderate skin petechiae and ecchymosis, as well as transient dizziness, palpitations, and chest tightness. No severe adverse events occurred, which proves that this intervention possesses a favorable clinical safety profile. The incidence of skin ecchymosis and overall adverse reactions was higher in the experimental group, which may be attributed to transient obstruction of local limb blood circulation induced by the inflation pressure of 200 mmHg. During clinical implementation, the inflation pressure can be appropriately adjusted according to patients' age, vascular status, and other individual conditions. Meanwhile, intensive monitoring should be performed throughout the training process to identify and manage adverse reactions in a timely manner, so as to further improve the safety of this intervention.

5. Summary

Remote ischemic postconditioning training can effectively inhibit excessive systemic inflammatory responses, improve cerebral hemodynamic parameters, and promote early neurological recovery and long-term prognosis in AIS patients after mechanical thrombectomy. As a non-invasive, easy-to-operate, and clinically safe intervention, RIPostC has important value for clinical promotion and application. However, this study is a single-center trial with a small sample size, and further large-sample studies are required to verify its clinical benefits in broader patient populations.

Disclosure statement

The authors declare no conflict of interest.

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