DOI: 10.53469/jcmp.2026.08(05).18

Study on the Efficacy and Mechanism of Electroacupuncture Combined with Transcranial Magnetic Stimulation in Treating Dystonia in Stroke Patients

Zehai Liu[1], Xu He[2,*]

[1]Department of Traditional Chinese Medicine, People's Hospital of Ganzhou Economic and Technological Development Zone, Ganzhou 341000, Jiangxi, China
[2]College of Integrated Traditional Chinese and Western Medicine, Dalian Medical University, Dalian 116000, Liaoning, China
Correspondence Author

Abstract: ***Objective:*** ***To evaluate the clinical efficacy and neural mechanism of electroacupuncture (EA) combined with transcranial magnetic stimulation (TMS) in patients with lower extremity dystonia after stroke. Methods: Fifty patients with post-stroke lower extremity dystonia admitted from January 2024 to January 2025 were randomly divided into two groups (n=25 each). The control group received routine rehabilitation plus sham EA and sham TMS. The treatment group received EA (on antagonist muscles) combined with repetitive TMS (rTMS) on the basis of routine rehabilitation. Before and after treatment, the modified Ashworth Scale (MAS), Fugl-Meyer Assessment for lower extremity (FMA-L), Postural Assessment Scale for Stroke (PASS), Functional Ambulation Category (FAC), and Stroke-Specific Quality of Life (SS-QOL) scale were used to evaluate functional improvements. Functional near-infrared spectroscopy (fNIRS) was used to detect changes in oxyhemoglobin concentration in motor-related brain regions, including the primary motor cortex (SMC), supplementary motor area (SMA), premotor cortex (PMC), and prefrontal cortex (PFC). Results: After treatment, the treatment group was significantly superior to the control group in all functional indicators (all P<0.05). The MAS score was significantly decreased (muscle tone improved by ≥1 grade), and FMA-L, PASS, FAC, and SS-QOL scores were significantly increased. fNIRS showed that the activation range of motor-related brain regions (SMC, SMA, PMC, PFC) was significantly expanded in the treatment group (P<0.05), whereas no significant changes were observed in the control group (P>0.05). Conclusion: On the basis of routine rehabilitation, EA combined with rTMS can effectively activate and expand motor-related brain regions in stroke patients, significantly reduce lower extremity muscle tone, improve motor function, walking ability and quality of life, with clear value for clinical promotion.***

Keywords: Electroacupuncture, Transcranial magnetic stimulation, Stroke, Lower extremity motor dysfunction, Dystonia.

1. Introduction

With the acceleration of population aging in China, the incidence of stroke has been increasing year by year. Lower extremity hypertonia is one of the most common limb dysfunctions after stroke, leading to difficulties in turning over, sitting, walking and other basic movements, severely reducing self-care ability and imposing a heavy burden on families and society [1]. Therefore, effectively reducing muscle tone of the affected limbs and improving spasticity after stroke are core goals of rehabilitation. EA enhances acupoint stimulation by combining acupuncture and electrical stimulation, while TMS improves limb spasticity through central neuromodulation. Both are effective interventions for post-stroke dystonia [2-4]. This study investigated the clinical efficacy and neural mechanism of EA combined with rTMS in patients with post-stroke lower extremity dystonia, aiming to provide evidence-based evidence for clinical treatment.

2. Materials and Methods

2.1 General Data

Fifty patients with post-stroke lower extremity dystonia admitted to the Department of Traditional Chinese Medicine of our hospital from January 2024 to January 2025 were enrolled and randomly divided into treatment group and control group using a random number table method, with 25 cases in each group. The control group included 18 males and 7 females, aged 40–84 years, with a mean age of (58.24±11.37) years. The treatment group included 17 males and 8 females, aged 45–80 years, with a mean age of (63.36±11.34) years. There were no significant differences between the two groups in gender, age, lesion type (cerebral infarction/intracerebral hemorrhage), or lesion location (supratentorial/infratentorial) (all P>0.05), indicating good comparability. This study was approved by the Medical Ethics Committee of People's Hospital of Ganzhou Economic and Technological Development Zone (Ethical Approval No.LLKY2024-02), and all patients signed informed consent.

2.2 Diagnostic Criteria

Stroke was diagnosed according to the Chinese Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke 2023 and Chinese Guidelines for the Diagnosis and Treatment of Cerebral Hemorrhage (2019) [5-6]. Lower extremity dystonia was diagnosed referring to the Chinese Expert Consensus on the Assessment and Treatment of Post-Stroke Spasticity (2021) [7], with a modified Ashworth Scale (MAS) score ≥1+ as the inclusion criterion.

2.3 Inclusion Criteria

① Meeting the diagnostic criteria of stroke and lower extremity dystonia; ② First onset or no residual lower extremity dysfunction from previous stroke; ③ Disease course 2 weeks–6 months, age 18–90 years; ④ Clear consciousness, no obvious cognitive impairment (MMSE score ≥24), unilateral lower extremity hypertonia; ⑤ Voluntary participation and signed informed consent.

2.4 Exclusion Criteria

① Not meeting the diagnostic and inclusion criteria; ② Previous lower extremity motor, osteoarticular or peripheral nerve diseases; ③ Complicated with severe cardiopulmonary, hepatic or renal diseases or critical condition; ④ With disturbance of consciousness, severe cognitive or mental disorders; ⑤ Contraindications to TMS, magnetic resonance examination, or skin damage precluding EA.

2.5 Criteria for Exclusion, Dropout and Termination

① Exclusion: Inconsistent with inclusion criteria or incomplete clinical data after enrollment; ② Dropout: Failure to receive treatment as scheduled, poor compliance, voluntary withdrawal or loss to follow-up; ③ Termination: Severe adverse reactions or emergencies requiring special intervention during treatment.

3. Treatment and Observation Methods

3.1 Basic Treatment

Both groups received basic interventions: regulation of blood pressure, blood glucose, blood lipid and other risk factors, neurotrophic and circulation-improving drugs; routine rehabilitation including physical therapy (joint mobilization, muscle strength training), occupational therapy (activities of daily living training), and speech therapy for patients with speech disorders, once daily, 6 days per week, for 4 consecutive weeks.

3.2 Control Group

Basic treatment combined with sham EA + sham TMS. Sham EA was performed at the same acupoints as the treatment group. After deqi, the EA device was connected with an intensity of 0 mA, and needles were retained for 20 minutes, once daily, 6 days per week. Sham TMS was performed in the same manner as the treatment group without actual magnetic output, once daily, 5 days per week, for 4 consecutive weeks.

3.3 Treatment Group

Basic treatment combined with EA on antagonist muscles + rTMS.

3.3.1 Electroacupuncture Treatment

Acupoints: Ququan (LR8), Yinbao (LR9), Yinmen (BL37), Chengfu (BL36), Zusanli (ST36), Yanglingquan (GB34), Shangjuxu (ST37), Xiajuxu (ST39), Yangfu (GB38), Xuanzhong (GB39), located according to Code for Names and Locations of Acupoints (GB/T12346-2021). Patients were placed in prone or lateral position. After routine disinfection, 0.25×40 mm sterile acupuncture needles were inserted to obtain deqi, connected to a Huatuo SDZ-III electronic acupuncture instrument with sparse-dense wave at 5 Hz, intensity adjusted to patient tolerance, and needles retained for 20 minutes. Once daily, 6 days per week, for 4 consecutive weeks.

3.3.2 rTMS Treatment

A MagTD60 magnetic stimulator (Yiruide, Wuhan) was used for high-frequency stimulation of the lower extremity representation in the primary motor cortex (M1) of the affected hemisphere. Parameters: frequency 10 Hz, intensity 80% resting motor threshold, burst stimulation (4 s per burst, 26 s interval), approximately 1200 pulses per session, 20 minutes per session. Once daily, 5 days per week, for 4 consecutive weeks.

3.4 Observation Indicators

① Functional indicators: MAS, FMA-L, PASS, FAC and SS-QOL were used to evaluate lower extremity muscle tone, motor function, postural control, walking ability and quality of life before treatment, at 2 weeks and at 4 weeks (discharge); ② Brain function indicators: fNIRS (Huichuang BS-3000) was used to detect oxyhemoglobin concentration and activation range in M1, SMA, PMC and PFC before treatment and at 4 weeks, analyzed using NirSpark software; ③ Safety indicators: Adverse reactions such as dizziness, headache, acupuncture-related injury and seizure were observed and recorded throughout the treatment.

3.5 Statistical Methods

SPSS 29.0 software was used for data analysis. Enumeration data were expressed as cases (%), and chi-square test was used for intergroup comparison. Normally distributed measurement data were expressed as mean ± standard deviation ($\bar{x}\pm s$), paired t-test for intragroup comparison and independent-samples t-test for intergroup comparison. Non-normally distributed measurement data were expressed as median (interquartile range) M (P25, P75), and rank-sum test was used. $P<0.05$ was considered statistically significant.

4. Results

4.1 Baseline Analysis

There were no significant differences between the two groups in gender, age, lesion type, lesion location and other baseline data (all $P>0.05$), indicating good comparability.

4.2 Comparison of Functional Indicators

Both groups showed significant improvements in FMA-L, PASS, FAC and SS-QOL scores over time (intragroup $P<0.05$). The treatment group showed greater improvements in all indicators than the control group ($P<0.05$).

4.3 fNIRS Results

After treatment, the activation range of motor-related brain regions (M1, SMA, PMC, PFC) was significantly expanded in the treatment group ($P<0.05$), while no significant changes were found in the control group ($P>0.05$).

4.4 MAS Muscle Tone Comparison

There was no significant difference in MAS grade distribution between the two groups at admission, 2 weeks or discharge (all P>0.05). However, the treatment group had a higher proportion of patients with reduced muscle tone to grade 0 or 1 at discharge.

4.5 Safety

No serious adverse reactions occurred in either group during treatment. All adverse events were mild and relieved spontaneously.

5. Discussion

The core pathological mechanism of post-stroke lower extremity dystonia is the loss of inhibition of spinal stretch reflex due to upper motor neuron injury. The inhibitory regulation of the spinal cord by the upper center is weakened, and the facilitation effect is relatively hyperactive, leading to abnormal hyperexcitability of extensors (quadriceps femoris) and suppressed excitability of flexors (biceps femoris, semimembranosus, etc.), thus breaking the flexor-extensor muscle tone balance and eventually manifesting as lower extremity spasticity [8-10]. Restoring the tension balance of flexor-extensor muscle groups is the key to improving post-stroke lower extremity spasticity. Based on the TCM theory of “inhibiting the strong and supporting the weak” combined with modern neuromodulation technology, this study adopted EA on antagonist muscles combined with rTMS to achieve dual intervention of peripheral muscle regulation and central nervous regulation, and achieved significant clinical efficacy.

As a modern extension of TCM acupuncture, EA directly enhances the neuromuscular excitability of lower extremity flexors (antagonist muscles) by acupuncture at antagonist muscle acupoints combined with electrical stimulation, antagonizes excessive spasticity of extensors, and restores the balance of flexor-extensor muscle tone [11]. In this study, EA acupoints were mainly selected from the Liver Meridian of Foot-Jueyin, Gallbladder Meridian of Foot-Shaoyang and Stomach Meridian of Foot-Yangming. Ququan and Yinbao can dredge Liver Meridian qi and relieve lower extremity adductor spasm; Yanglingquan and Xuanzhong are the influential points of tendons and marrow, which can relax tendons and unblock collaterals, strengthen tendons and bones; Zusanli, Shangjuxu and others can invigorate the spleen and replenish qi, nourish tendons and vessels. All acupoints work together to relax tendons and relieve spasm, and regulate muscle tone. Modern studies have shown that EA can improve post-stroke limb spasticity through multiple pathways: inhibiting ferroptosis of cortical nerve cells [12-13], regulating proliferation and differentiation of neural stem cells in the cortical M1 area [14], upregulating the expression of KCC2 and GABAARα1 to exert the inhibitory effect of γ-aminobutyric acid [15], inhibiting M1 polarization of microglia, blocking the NF-κB/NLRP3 pathway, and reducing inflammatory response and apoptosis in the brain [16-17], so as to achieve neuroprotection and functional repair at cellular and molecular levels.

As a non-invasive central neuromodulation technique, high-frequency rTMS on the lower extremity representation of M1 in the affected hemisphere can activate cortical motor neurons through magnetoelectric effect, enhance the inhibitory regulation of upper center on spinal stretch reflex, reduce abnormal excitability of extensors, and promote neural remodeling in motor-related brain regions [18]. In this study, rTMS was applied with 10 Hz high-frequency stimulation and 80% RMT intensity, which can effectively activate M1 neurons, expand the activation range of motor-related brain regions, and improve the regulation ability of the central nervous system on lower extremity movement.

The fNIRS results of this study showed that the activation range of motor-related brain regions such as M1, SMA, PMC and PFC was significantly expanded in the treatment group after treatment, suggesting that EA combined with rTMS can promote neural remodeling of motor-related brain regions and enhance functional connectivity between brain regions through peripheral-central synergy, which is an important neural mechanism for combined treatment to improve lower extremity motor function. As a non-invasive and real-time brain function detection technique, fNIRS can directly reflect neuronal activity in brain regions through changes in oxyhemoglobin concentration, providing a reliable objective basis for exploring the neural mechanism of stroke rehabilitation [19].

Clinical functional evaluation results showed that both groups had improvements in all indicators after treatment, but the improvement range of the treatment group was significantly better than that of the control group, indicating that the therapeutic effect of EA combined with rTMS is superior to single routine rehabilitation. This combined regimen achieves dual regulation of peripheral muscles and central nerves: peripheral EA stimulates antagonist muscles to restore muscle tension balance, and central rTMS activates motor brain regions to achieve neural regulation. The synergistic effect can more effectively reduce lower extremity muscle tone, improve motor function and patients’ quality of life, with no serious adverse reactions during treatment and good safety.

This study has certain limitations: small sample size and single-center design may lead to bias; no long-term follow-up was conducted, so the long-term efficacy of combined treatment needs further observation; the molecular regulation mechanism of EA combined with rTMS was not deeply explored. Future studies can expand the sample size, carry out multi-center and long-term follow-up studies, and combine proteomics and molecular biology techniques to further reveal the underlying mechanism.

Summary: this study demonstrates that electroacupuncture (EA) combined with repetitive transcranial magnetic stimulation (rTMS) exerts synergistic therapeutic effects on post-stroke lower limb spasticity. The intervention regulates central-peripheral pathways to promote neural plasticity and balance muscle tone, while multi-level mechanisms modulate molecular signaling, cellular function, brain activity, and limb recovery. These effects translate into reduced spasticity, improved motor function, and enhanced quality of life, highlighting the potential of combined neuromodulation for stroke rehabilitation (Figure 1).

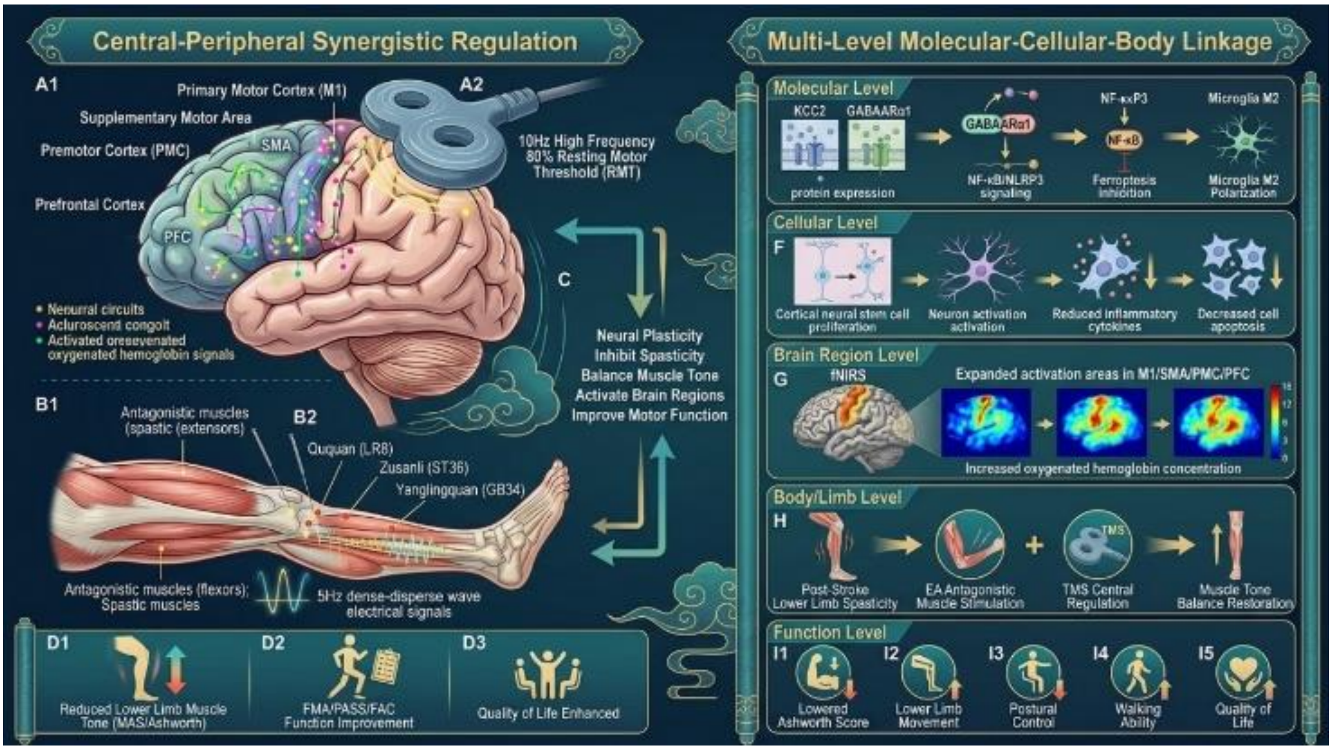

Figure 1: Electroacupuncture Combined with rTMS Alleviates Post-Stroke Lower Limb Spasticity via Central-Peripheral Synergistic and Multi-Level Molecular-Cellular-Body Regulatory Mechanisms

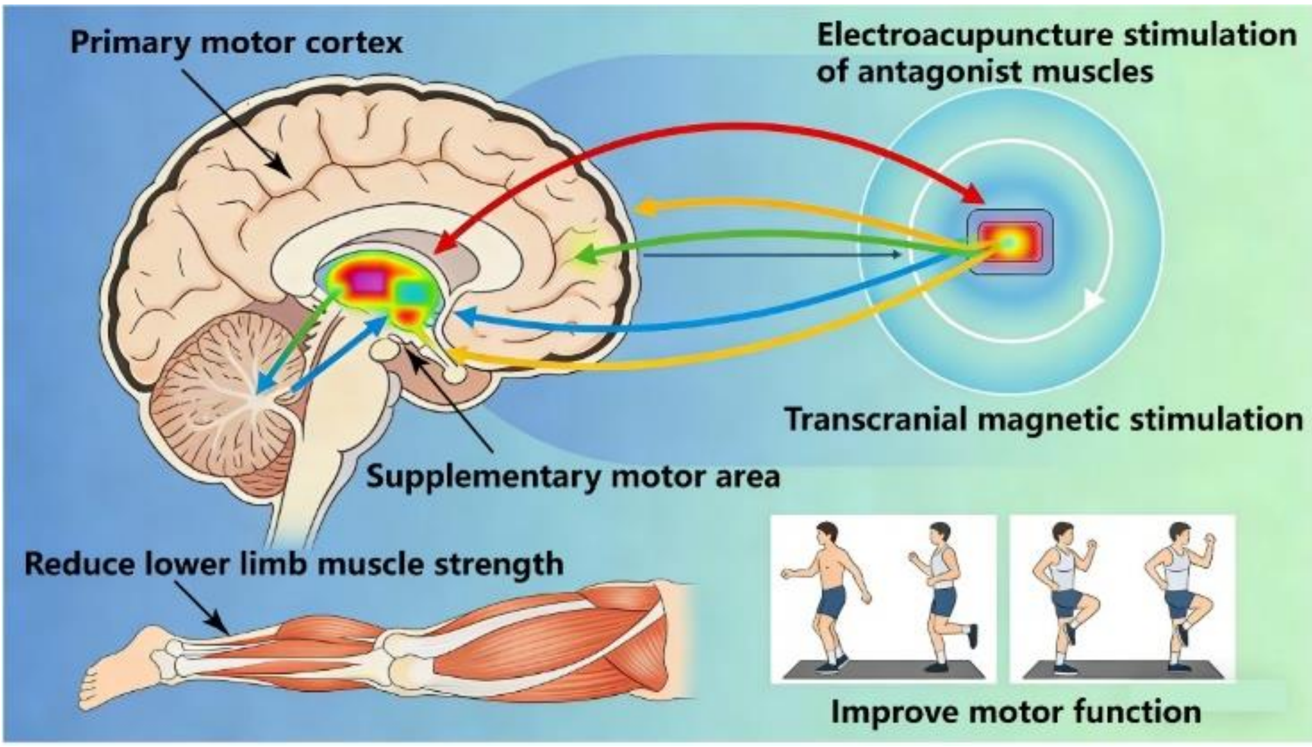

Figure 2: Schematic diagram of the study on the effect of electroacupuncture combined with transcranial magnetic stimulation on dystonia in stroke patients

6. Conclusion

On the basis of routine rehabilitation, EA combined with rTMS in the treatment of post-stroke lower extremity dystonia can activate and expand motor-related brain regions such as the primary motor cortex and supplementary motor area, achieve dual regulation of peripheral muscles and central nerves, effectively reduce lower extremity muscle tone, improve lower extremity motor function, postural control and walking ability, and significantly improve quality of life, with good safety and significant clinical application value, worthy of promotion in primary hospitals and rehabilitation departments (Figure 2).

Fundings

Science and Technology Bureau Project of Ganzhou City, Jiangxi Province (No. GZ2024ZSF869).

References

[1] Winstein CJ, Wolf SL, Dromerick AW, et al. Effect of a Task-Oriented Rehabilitation Program on Upper Extremity Recovery Following Motor Stroke: The ICARE Randomized Clinical Trial. JAMA. 2016;315(6):571-581. doi:10.1001/jama.2016.0276

[2] Schlaug G, Cassarly C, Feld JA, et al. Safety and efficacy of transcranial direct current stimulation in addition to constraint-induced movement therapy for post-stroke motor recovery (TRANSPORT2): a phase 2, multicentre, randomised, sham-controlled triple-blind trial. Lancet Neurol. 2025;24(5):400-412. doi:10.1016/S1474-4422(25)00044-4

[3] Chen L, Gao H, Wang Z, et al. Vagus nerve electrical stimulation in the recovery of upper limb motor functional impairment after ischemic stroke. Cogn Neurodyn. 2024;18(5):3107-3124. doi:10.1007/s11571-024-10143-8

[4] Graham KR, Hayes KD, Meehan SK. Combined Peripheral Nerve Stimulation and Controllable Pulse Parameter Transcranial Magnetic Stimulation to Probe Sensorimotor Control and Learning. J Vis Exp. 2023;(194):10.3791/65212. Published 2023 Apr 21. doi:10.3791/65212

[5] Li S, Gu HQ, Li H, et al. Reteplase versus Alteplase for Acute Ischemic Stroke. N Engl J Med. 2024;390(24):2264-2273. doi:10.1056/NEJMoa2400314

[6] Yu Z, Tao C, Xiao A, et al. Chinese multidisciplinary guideline for management of hypertensive intracerebral hemorrhage. Chin Med J (Engl). 2022;135(19):2269-2271. Published 2022 Oct 5. doi:10.1097/CM9.0000000000001976

[7] Wang J, Wu B, Tong Y, Wang X, Lu Z, Wang W. Effect of acupuncture combined with rehabilitation training on sensory impairment of patients with stroke: a network meta-analysis. BMC Complement Med Ther. 2024;24(1):102. Published 2024 Feb 26. doi:10.1186/s12906-024-04401-9

[8] Ho CSH, Wang J, Tay GWN, et al. Interpretable deep learning model for major depressive disorder assessment based on functional near-infrared spectroscopy. Asian J Psychiatr. 2024; 92: 103901. doi:10.1016/j.ajp.2023.103901

[9] Blumberger DM, Vila-Rodriguez F, Thorpe KE, et al. Effectiveness of theta burst versus high-frequency repetitive transcranial magnetic stimulation in patients with depression (THREE-D): a randomised non-inferiority trial. Lancet. 2018; 391(10131): 1683-1692. doi:10.1016/S0140-6736(18)30295-2

[10] Dawson J, Abdul-Rahim AH, Kimberley TJ. Neurostimulation for treatment of post-stroke impairments. Nat Rev Neurol. 2024;20(5):259-268. doi:10.1038/s41582-024-00953-z

[11] Wu C, Wang Q, Xu Z, Deng C, Tang C. Bioinformatics analysis of electroacupuncture treatment for ischemic stroke: exploring transcriptional regulatory mechanisms mediated by super-enhancers. Front Neurosci. 2025; 19: 1522466. Published 2025 Mar 5. doi:10.3389/fnins.2025.1522466

[12] Kang XY, Gao CF, Guo LQ, et al. Electroacupuncture treatment for post-stroke oropharyngeal dysphagia: a randomized controlled trial. Acupunct Med. 2025;43(4):187-197. doi:10.1177/09645284251365647

[13] Cheng J, Ma X, Tao J, Jiang X, Chen P, Duan X. Neuroprotective effects of ethanol extraction from Rubia yunnanensis Diels on chronic cerebral hypoperfusion: modulation of the System Xc-/GSH/GPX4 axis to alleviate oxidative stress and ferroptosis. Front Pharmacol. 2025; 16:1552228. Published 2025 Feb 25. doi:10.3389/fphar.2025.1552228

[14] Wang Q, Wei M, Wu R, et al. Corilagin reduces ischemic stroke damage by neural stem cell-mediated neurorepair. Eur J Pharmacol. 2026; 1015: 178555. doi:10.1016/j.ejphar.2026.178555

[15] Wang YL, Qi YN, Wang W, et al. Effects of decompression joint Governor Vessel electro-acupuncture on rats with acute upper cervical spinal cord injury. Neural Regen Res. 2018; 13(7): 1241-1246. doi:10.4103/1673-5374.235062

[16] Zhang XH, Cui H, Zheng SM, et al. Electroacupuncture regulates microglial polarization via inhibiting NF-κB/COX2 pathway following traumatic brain injury. Brain Res. 2023; 1818: 148516. doi:10.1016/j.brainres.2023.148516

[17] Luo L, Lin S, Hu G, et al. Molecular mechanism of Rolupram reducing neuroinflammation in noise induced tinnitus mice through TLR4/NF kB/NLRP3 protein/caspase-1/IL-1 β signaling pathway. Int J Biol Macromol. 2024; 278(Pt 4): 134987. doi:10.1016/j.ijbiomac.2024.134987

[18] Yang K, Zhang H, Hu G, et al. Electroacupuncture for patients with spasticity after stroke: A protocol for systematic review and meta-analysis. Medicine (Baltimore). 2021; 100(7): e24859. doi:10.1097/MD.0000000000024859

[19] Zhou X, Zhang Q, Zhu H, Ouyang G, Wang X, Cai Y. High Carbonyl Graphene Oxide Suppresses Colorectal Cancer Cell Proliferation and Migration by Inducing Ferroptosis via the System Xc-/GSH/GPX4 Axis. Pharmaceutics. 2024;16(12):1605. Published 2024 Dec 17. doi:10.3390/pharmaceutics16121605