

Original Article

Clinical study on acupuncture for improving neck muscle stiffness, cervical function, and hemodynamics in patients with unilateral pain of acute neck-type cervical spondylosis

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Abstract: Objective: To investigate acupuncture's effects on neck muscle stiffness, cervical function, pain, and vertebral artery hemodynamics in acute unilateral neck-type cervical spondylosis (NTCS), and analyze correlations between muscle stiffness and hemodynamics as well as long-term recurrence. Methods: This retrospective study initially included 216 acute NTCS patients from the Third People's Hospital of Gansu Province (April 2021-September 2024). After propensity score matching, 170 patients were enrolled (85 each in the observation group and the control group). Outcomes measured pre- and post-treatment included shear wave velocity (SWV) of the trapezius, semispinalis cervicis, and splenius capitis muscles; Neck Disability Index (NDI); visual analogue scale (VAS); vertebral artery peak systolic velocity (PSV) and resistance index (RI). Adverse events and recurrence at 6 and 12 months were recorded. Correlations between SWV and hemodynamic parameters were examined. Results: After matching, baseline characteristics were comparable (all $P > 0.05$). Post-treatment, the acupuncture group showed significantly lower SWV in all three muscles, lower NDI and VAS scores, higher PSV, and lower RI compared to controls (all $P < 0.05$). Total adverse reaction rate was 10.59% vs. 22.35% ($P = 0.039$). Before treatment, SWV was negatively correlated with PSV and positively correlated with RI ($P < 0.05$). Six-month recurrence rates were similar ($P > 0.05$), whereas at 12 months the acupuncture group had a significantly lower recurrence rate ($P < 0.05$). Conclusion: Acupuncture effectively reduces neck muscle stiffness, alleviates pain, improves cervical function and local hemodynamics, with a favorable safety profile and lower long-term recurrence in patients with acute unilateral pain NTCS.

Keywords: Unilateral pain neck-type cervical spondylosis, muscle stiffness, acupuncture, cervical spine function, hemodynamics

Introduction

According to statistics, the unilateral pain neck-type is the most common cervical spondylosis type. The main clinical manifestation presents as one-sided pain and stiffness of the neck muscle and may be associated with limited movement of the cervical spinal column and tenderness on palpation at the site. This condition is particularly common in people who work at desks for extended periods, those addicted to smartphones, and similar groups [1]. In recent years, with changes in lifestyle,

the incidence of this disease has shown a younger trend, seriously affecting patients' quality of life and work efficiency [2]. As a key pathological manifestation of the disease, neck muscle stiffness can further aggravate cervical spine dysfunction by stretching cervical joints and destroying mechanical balance, while persistent muscle spasm leads to insufficient local blood perfusion, which becomes an important inducement for chronicity and recurrence of the disease. Therefore, it is urgent to find safe and effective targeted treatment options [3, 4].

Various clinical treatment methods for unilateral pain neck-type cervical spondylosis are presently available. The principal means of drug treatment is mainly non-steroidal anti-inflammatory drugs (NSAIDs) that can rapidly relieve pain, but are prone to cause damage to the gastrointestinal tract during long-term use, and cannot improve the muscle stiffness, the core of the problem [5]. Physical therapy and conventional rehabilitation training can relieve symptoms temporarily, but the curative effect is short, the recurrence rate of disease is high, and it is difficult to fundamentally solve the muscle spasm and hemodynamic abnormalities correlation [6]. Acupuncture is a hallmark modality of traditional Chinese medicine (TCM). Drawing on the classic concepts of dredging meridians and regulating qi and blood, it has seen widespread clinical use for cervical spondylosis [7]. Modern clinical studies have preliminarily confirmed that acupuncture can relieve muscle spasm and reduce pain by regulating the neurohumoral regulatory system [8-10]. Existing studies mainly study overall cervical spondylosis, with few targeted studies of unilateral pain, and there is also no systematic study to simultaneously explore the synergistic improvement effect of acupuncture on muscle stiffness, cervical spine function as well as hemodynamics. The mechanism of action has not been fully clarified, which makes it difficult to provide sufficient evidence of clinical precise treatment.

This study aimed to investigate how much acupuncture improves neck muscle stiffness, cervical spine function scores, and local hemodynamics in unilateral pain neck-type cervical spondylosis patients. This follows from previous studies in this area. We also examined whether the alteration in muscle stiffness resulting from acupuncture is connected to altered perfusion i.e. altered blood flow. We aim to provide greater clinical evidence to support the use of acupuncture treatment for this condition to help refine future treatment strategies.

Methods

General information

We looked back at patients who came to our hospital between April 2021 and September 2024 with acute-stage unilateral pain neck-type cervical spondylosis. A total of 216 cases

met the criteria and were included. Among them, 112 received acupuncture, which made up the observation group. The other 104 got conventional treatment (oral NSAIDs plus neck exercises), forming the control group. This study was approved by the Third People's Hospital of Gansu Province.

Inclusion and exclusion criteria

Inclusion criteria: (1) Conforming to the diagnostic criteria of neck-type cervical spondylosis [11], with manifestations of unilateral neck muscle pain and stiffness, and the course of disease in the acute stage (onset ≤ 2 weeks); (2) Aged 18-60 years; (3) No targeted treatment for cervical spondylosis (such as acupuncture, physical therapy, analgesic drugs, etc.) received in the past month.

Exclusion criteria: (1) Complicated with other types of cervical spondylosis such as radiculopathy or myelopathy, or organic lesions such as cervical fracture, dislocation, tumor, or infection; (2) Having contraindications to acupuncture (such as coagulation dysfunction, skin infection, history of acupuncture syncope) or a history of allergy to non-steroidal anti-inflammatory drugs; (3) Complicated with severe diseases of heart, liver, kidney and other organs, or mental illness, cognitive impairment; (4) Pregnant or lactating women; (5) Lost to follow-up or with poor compliance during the follow-up period, unable to complete treatment and measurement of observation indicators.

Treatment methods

Observation group (acupuncture treatment): Acupuncturist qualification: All acupuncture treatments were performed by licensed attending physicians or chief physicians of Traditional Chinese Medicine, each with a minimum of 5 years of clinical experience in acupuncture. To ensure treatment consistency, all acupuncturists underwent a unified standard operating procedure (SOP) training prior to the study period, and the same detailed needling protocol was strictly followed for every patient, as recorded in the medical charts.

Acupoint selection: Ipsilateral Fengchi (GB20), Tianzhu (BL10), Jianjing (GB21), Jingbailao (EX-HN14), Ashi points (the most prominent area of

neck muscle stiffness and tenderness), combined with bilateral Dazhui (GV14) and Hegu (LI4). The locations of the acupoints followed the WHO Standard Acupuncture Point Locations.

Needling procedure: Patients were in a sitting position with the neck and shoulders fully exposed. After routine skin disinfection with 75% alcohol, disposable sterile acupuncture needles (0.30 mm × 40 mm, Huatuo brand, Suzhou Medical Appliance Factory, China) were used. The needling methods were as follows: GB20 (Fengchi): Oblique insertion directed toward the tip of the nose, 0.8-1.0 cun in depth. BL10 (Tianzhu): Perpendicular insertion, 0.5-0.8 cun in depth. GB21 (Jianjing): Perpendicular insertion, 0.5-0.8 cun in depth (care taken to avoid deep needling to protect the pleural apex). EX-HN14 (Jingbailao): Perpendicular insertion, 0.5-0.8 cun in depth. Ashi points: Perpendicular insertion, 1.0-1.5 cun in depth depending on the thickness of the local muscles. GV14 (Dazhui): Perpendicular insertion, 0.5-1.0 cun in depth. LI4 (Hegu): Perpendicular insertion, 0.5-1.0 cun in depth. Upon achieving the deqi sensation (a composite sensation of soreness, numbness, distension, and heaviness), the even reinforcing-reducing manipulation (Pingbu Pingxie) was applied using the twisting method. The twisting angle was maintained between 90° and 180°, with a lifting-thrusting amplitude of 0.3-0.5 cm and a frequency of 60-90 times per minute. The needles were retained for 30 minutes. During the retention period, manipulation was repeated for approximately 30 seconds at 15-minute intervals (i.e., at 0, 15, and 30 minutes) to maintain the deqi sensation throughout the session.

Treatment course: Treatment was administered once daily, five times per week (Monday to Friday), for four consecutive weeks, yielding a total of 20 sessions. Compliance was monitored via treatment logs; patients were considered adherent if they completed at least 16 sessions.

Control group (conventional treatment): (1) Medication: patients took oral non-steroidal anti-inflammatory drugs - specifically, ibuprofen sustained-release capsules - at a dose of 0.3 g per intake, twice daily, and always after meals; (2) Neck functional exercise: Patients were

guided to perform slow neck flexion-extension, lateral flexion and rotation exercises (each movement held for 5 seconds, 10 times per group, 3 groups a day), combined with neck muscle relaxation exercises (alternating shoulder shrugging and sinking, 15 times per group, 2 groups a day). Drug administration and functional exercise lasted for 4 weeks, during which the medication time was adjusted according to patients' gastrointestinal reactions to avoid fasting medication.

Observation indicators

Baseline data: A balance test was performed between the two groups using variables including gender, age, BMI, course of disease, affected side distribution, desk work history, neck trauma history, concurrent neck-shoulder myofasciitis, smoking, and drinking.

Degree of neck muscle stiffness: Using a Supersonic Imagine AixPlorer system for shear wave elastography, we measured SWV in the ipsilateral trapezius (2 cm lateral to C7), semispinalis cervicis (1 cm lateral to C3-C5), and splenius capitis (2 cm lateral to C2-C4). Measurements were done before and at 4 weeks after treatment, each muscle three times, then averaged. Higher average SWV indicates greater muscle stiffness.

Cervical spine function and pain degree: (1) Function of cervical spine. Function was assessed using the Neck Disability Index (NDI) before treatment and also 4 weeks after treatment. The NDI is made up of 10 areas that include pain intensity and activities of daily living. NDI produces a final score from 0 to 50. The greater the score the worse the cervical dysfunction [12]. (2) Discomfort intensity. The intensity of unilateral neck pain was assessed with Visual Analogue Scale (VAS) at baseline and 4 weeks. The VAS has numerical values from 0 to 10, where 0 means no pain and 10 means unbearable pain. Higher score denotes higher pain severity [13].

Vertebral artery hemodynamic indicators: We used Philips iU22 color Doppler ultrasound machine to measure peak systolic velocity (PSV) and resistance index (RI) of ipsilateral vertebral artery. The measurements were carried out prior to and at 4 weeks after the treatment. The patients lie flat on their back turned

slightly towards the side of the body that has no complications. After obtaining a good view of the overall vertebral artery, we focused on the intervertebral segment to take our readings. Each of the said parameters was taken three times and the final result was obtained by averaging the three values.

Adverse reactions: The kinds of adverse reaction like local pain, subcutaneous hemorrhage, gastrointestinal discomfort, rash, etc. and the number of occurrence in the two groups during treatment were recorded and the incidence of adverse reaction was calculated.

Recurrence rate: All patients were followed up at 6 and 12 months after the completion of treatment. The primary endpoint was disease recurrence, defined as the fulfillment of any two of the following criteria: (1) Recurrence of unilateral neck pain with a VAS score ≥ 4 ; (2) Increase in shear wave velocity (SWV) of any of the three measured neck muscles by $\geq 30\%$ compared with the post-treatment value; (3) Increase in the Neck Disability Index (NDI) score by $\geq 20\%$ compared with the post-treatment value. No patients were lost to follow-up; all 170 propensity-score-matched patients (85 per group) completed the entire 12-month follow-up period. The date of recurrence was recorded as the first time point at which the above criteria were met.

Correlation analysis

Before treatment, we assessed the relation between the neck muscle SWV (trapezius, semispinalis cervicis, splenius capitis) and vertebral artery PSV and RI. Two separate analyses were conducted for the observation group and the control group.

Statistical analysis

We ran all analyses using SPSS version 25.0. Quantitative data were expressed as mean $\pm$ standard deviation. The Shapiro-Wilk test was performed to verify the normality of data distribution. Independent t-test or Chi-square test was used for the comparison of baseline characteristics between the groups. For repeatedly measured data (SWV, NDI, VAS, PSV, and RI), a two-way repeated-measures analysis of variance was conducted, with group (observation group vs. control group) and time (before treat-

ment vs. after treatment) as the influencing factors. The group-by-time interaction effect was regarded as the primary indicator for evaluating differences in therapeutic efficacy. Propensity score matching was performed to balance baseline covariates (1:1 nearest neighbor matching, with a caliper value set at 0.2 standard deviations of the logit propensity score). Correlations were assessed using Pearson's correlation coefficient. As for recurrence rates, we did Kaplan-Meier survival curves and compared them with the Log-rank test. In all cases, a *P* value below 0.05 was considered statistically significant.

Results

Baseline comparability between the two groups

A total of 216 patients were enrolled in this study, including 112 patients in the observation group and 104 patients in the control group. After propensity score matching, 170 patients were finally included, with 85 patients assigned to each group. Baseline characteristics including gender, age, body mass index, disease duration, affected side distribution, history of desk work, history of neck trauma, presence or absence of cervicospinal myofasciitis, smoking history and drinking history were compared between the two groups after matching. No statistically significant between-group differences were observed for all indicators (all *P* > 0.05), indicating good comparability between the two groups in terms of general demographic characteristics, medical history and lifestyle factors. See **Table 1**.

Comparison of neck muscle stiffness between the groups before and after treatment

A two-way repeated measures ANOVA was performed on the SWV of the trapezius, semispinalis cervicis, and splenius capitis muscles. The Group $\times$ Time interaction effect was statistically significant for all three muscles (*P* < 0.001), indicating that the pattern of change over time differed between the two groups. Baseline SWV values were similar between the two groups (all *P* > 0.05). After treatment, the observation group achieved significantly lower SWV in all three muscles compared to the control group (all *P* < 0.001). Detailed data are shown in **Table 2**.

Table 1. Baseline data

Baseline Characteristics	Before Propensity Score Matching				After Propensity Score Matching			
	Observation group (n = 112)	Control group (n = 104)	t/χ ²	P	Observation group (n = 85)	Control group (n = 85)	t/χ ²	P
Gender (male/female)	58/54	57/47	0.198	0.657	44/41	45/40	0.024	0.878
Age (years)	47.16±9.78	44.60±8.56	2.055	0.041	45.49±9.43	45.06±8.70	0.313	0.755
BMI (kg/m ²)	23.67±2.77	23.95±2.29	0.825	0.410	23.67±2.68	23.81±2.30	0.350	0.727
Course of disease (months)	6.80±1.98	7.17±1.73	1.462	0.145	7.08±1.95	7.18±1.68	0.338	0.736
Affected side (left/right)	58/54	56/48	0.198	0.657	45/40	44/41	0.024	0.878
History of desk work (≥ 6 h/d)	79 (70.54)	67 (64.42)	0.920	0.338	57 (67.06)	54 (63.53)	0.234	0.629
History of neck trauma	14 (12.50)	17 (16.35)	0.649	0.421	13 (15.29)	13 (15.29)	0.000	1.000
Complicated with neck-shoulder myofascitis	46 (41.07)	39 (37.50)	0.288	0.591	29 (34.12)	34 (40.00)	0.631	0.427
Smoking history	29 (25.89)	22 (21.15)	0.671	0.413	19 (22.35)	19 (22.35)	0.000	1.000
Drinking history	24 (21.43)	18 (17.31)	0.585	0.445	16 (18.82)	16 (18.82)	0.000	1.000

Note: BMI, body mass index.

Table 2. Pre- and post-treatment neck muscle stiffness in the two groups

		Observation group (n = 85)	Control group (n = 85)	Group × Time F	P
Trapezius muscle SWV	Before treatment	4.64±0.56	4.54±0.43		
	After treatment	2.44±0.39	2.94±0.41***	47.524	P < 0.001
Semispinalis cervicis muscle SWV	Before treatment	4.14±0.48	4.19±0.58		
	After treatment	2.53±0.40	3.11±0.39***	51.383	P < 0.001
Splenius capitis muscle SWV	Before treatment	4.40±0.44	4.36±0.50		
	After treatment	2.96±0.30	3.43±0.40***	43.638	P < 0.001

Note: SWV, shear wave velocity. F and P values refer to the Group × Time interaction effect from two-way repeated measures ANOVA. ***P < 0.001 compared with the observation group at the same time point. Post-hoc between-group comparisons at each time point were adjusted using the Bonferroni method.

Table 3. Pre- and post-treatment cervical function and pain scores by group

		Observation group (n = 85)	Control group (n = 85)	Group × Time F	P
NDI	Before treatment	38.95±2.30	39.46±2.62		
	After treatment	18.81±1.87	22.22±2.01***	68.269	P < 0.001
VAS	Before treatment	7.89±1.36	7.95±1.42		
	After treatment	4.16±1.12	6.56±1.24***	105.143	P < 0.001

Note: NDI, Neck Disability Index; VAS, visual analogue scale. F and P values refer to the Group × Time interaction effect from two-way repeated measures ANOVA. ***P < 0.001 compared with the observation group at the same time point. Post-hoc between-group comparisons at each time point were adjusted using the Bonferroni method.

Comparing cervical function and pain levels between the groups before and after treatment

For both the NDI and the VAS pain score, repeated measures ANOVA revealed significant Group × Time interactions (P < 0.001). No significant baseline differences were found between the two groups (both P > 0.05). At the post-treatment assessment, the observation group demonstrated significantly lower NDI and VAS scores than the control group (P < 0.001

for both), indicating greater improvements in cervical function and pain relief. See **Table 3**.

Comparing local hemodynamics between the groups before and after treatment

Repeated measures ANOVA of the vertebral artery hemodynamic parameters showed significant Group × Time interactions for both PSV and RI (P < 0.001). The two groups were comparable at baseline for both parameters (P > 0.05). Following treatment, the observation

Table 4. Pre- and post-treatment local hemodynamic parameters by group

		Observation group (n = 85)	Control group (n = 85)	F	P
Vertebral artery PSV (cm/s)	Before treatment	31.58±4.07	32.32±5.33	24.906	< 0.001
	After treatment	41.99±5.94	37.10±5.42***		
Ipsilateral vertebral artery RI	Before treatment	0.71±0.11	0.72±0.14	11.350	< 0.001
	After treatment	0.57±0.08	0.63±0.11***		

Note: PSV, peak systolic velocity; RI, resistance index. F and P values refer to the Group × Time interaction effect from two-way repeated measures ANOVA. ***P < 0.001 compared with the observation group at the same time point. Post-hoc between-group comparisons at each time point were adjusted using the Bonferroni method.

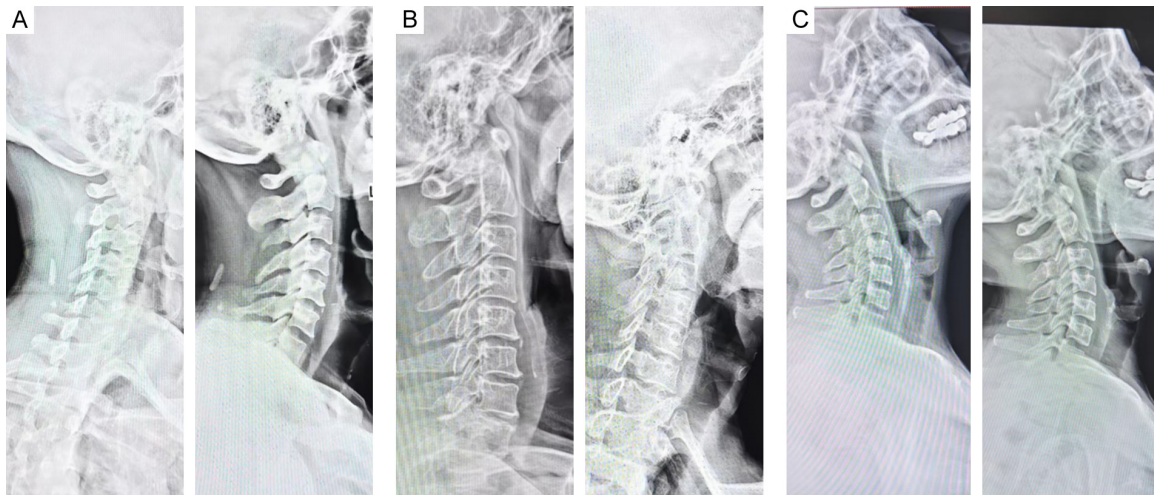


Figure 1. Lateral cervical spine X-rays of representative patients from both groups, taken before and after treatment. A. A typical observation group patient, pre- and post-treatment. B. Another observation group patient, pre- and post-treatment. C. A typical control group patient, pre- and post-treatment.

group exhibited a significantly higher PSV and a significantly lower RI compared to the control group ($P < 0.001$ for each), suggesting more pronounced improvements in local blood perfusion. See **Table 4**.

Imaging manifestations of the cervical spine before and after treatment

Typical cases from both groups were selected for comparative imaging evaluation using lateral cervical spine X-rays before and after treatment. The results showed that in the observation group before treatment, the physiological curvature of the cervical spine was significantly straightened, with segmental reverse curvature in some regions; varying degrees of osteophyte formation were observed at the margins of the C3-C7 vertebral bodies, accompanied by mild narrowing of the intervertebral spaces, disordered cervical alignment, increased density of the cervical soft tissues, and obvious swelling.

After treatment, the physiological curvature of the cervical spine was markedly restored, the cervical alignment became regular, the degree of intervertebral space narrowing was alleviated, and the soft-tissue swelling and increased density were significantly reduced, with no obvious progression of vertebral osteophytes (**Figure 1A, 1B**). In the control group, the pre-treatment imaging findings were similar to those in the observation group; after treatment, there were no significant improvements in the physiological curvature, intervertebral space width, or cervical alignment, and the abnormal soft-tissue imaging manifestations were not obviously relieved (**Figure 1C**).

Comparing adverse reactions between the two groups during treatment

In the observation group, the adverse reactions were local pain, subcutaneous hemorrhage, and gastrointestinal discomfort. In the control

Table 5. Adverse reaction summary

	Observation group (n = 85)	Control group (n = 85)	χ^2	P
Local pain	3 (3.53)	9 (10.59)		
Subcutaneous hemorrhage	4 (4.71)	0 (0.00)		
Gastrointestinal discomfort	2 (2.35)	7 (8.23)		
Rash	0 (0.00)	3 (3.53)		
Total adverse reactions	9 (10.59)	19 (22.35)	4.276	0.039

group, patients experienced local pain, gastrointestinal discomfort, and rash. The overall adverse reaction rate turned out to be lower in the observation group than that in the control group, and the difference was statistically significant ($P = 0.039$). See **Table 5**.

Pre-treatment correlation between neck muscle stiffness and hemodynamics

Before treatment, a consistent pattern emerged in both groups. For the observation group, SWV of the trapezius, semispinalis cervicis, and splenius capitis showed a strong negative correlation with ipsilateral PSV and a strong positive correlation with RI ($P < 0.001$ for each). The control group yielded virtually identical results for the same three muscles (all $P < 0.001$). See **Figure 2**.

Comparing recurrence rates between the two groups

We followed up on recurrence at 6 and 12 months after treatment. In the observation group, 12 patients had recurred by 6 months, and 22 by 12 months. In the control group, 18 recurred within 6 months, and 39 by 12 months. A Kaplan-Meier curve comparison showed no significant difference at 6 months ($P > 0.05$). However, at 12 months, the control group's recurrence rate was significantly higher than that of the observation group ($P < 0.05$). See **Figure 3**.

Subgroup analysis: comparison of efficacy differences in patients with different clinical characteristics

Subgroup analyses by disease duration and desk work history: To explore whether treatment effects differed by clinical characteristics, we conducted prespecified subgroup analyses stratified by disease duration (≤ 6 months vs. > 6 months) and history of desk

work (≥ 6 h/d vs. < 6 h/d). Between-group comparisons of pre-to-post treatment change scores for seven outcome measures within each subgroup were performed using independent-samples t-tests, with Bonferroni correction applied to adjust for multiple outcome comparisons (adjusted $\alpha = 0.05/7 \approx 0.007$). Disease duration: In the shorter-duration subgroup (≤ 6 months), patients in the observation group exhibited significantly greater reductions in SWV of the trapezius, semispinalis cervicis, and splenius capitis muscles, larger decreases in NDI and VAS scores, and more pronounced improvements in vertebral artery PSV (increase) and RI (decrease) compared with the control group (all corrected $P < 0.001$ for six outcomes; corrected $P = 0.002$ for RI change; **Table 6**). In the longer-duration subgroup (> 6 months), the observation group similarly outperformed the control group across all seven outcome measures (all corrected $P < 0.001$; **Table 6**). Notably, the magnitude of improvement in the shorter-duration observation subgroup was numerically greater than that observed in the longer-duration observation subgroup across all outcomes, suggesting that earlier acupuncture intervention may yield more favorable responses. Desk-work history: Among patients with prolonged desk-work exposure (≥ 6 h/d), the observation group demonstrated significantly greater improvements than the control group in all muscle stiffness, function, pain, and hemodynamic parameters (all corrected $P < 0.001$; **Table 6**). Consistent results were observed in the subgroup without prolonged desk work (< 6 h/d), where the observation group also showed significantly superior outcomes across all seven measures (all corrected $P < 0.001$; **Table 6**). Despite the uniformly significant findings, the effect sizes in the long-desk-work subgroup were numerically larger than those observed in the shorter-desk-work subgroup, consistent with the notion that patients with greater occupational exposure to sustained neck loading

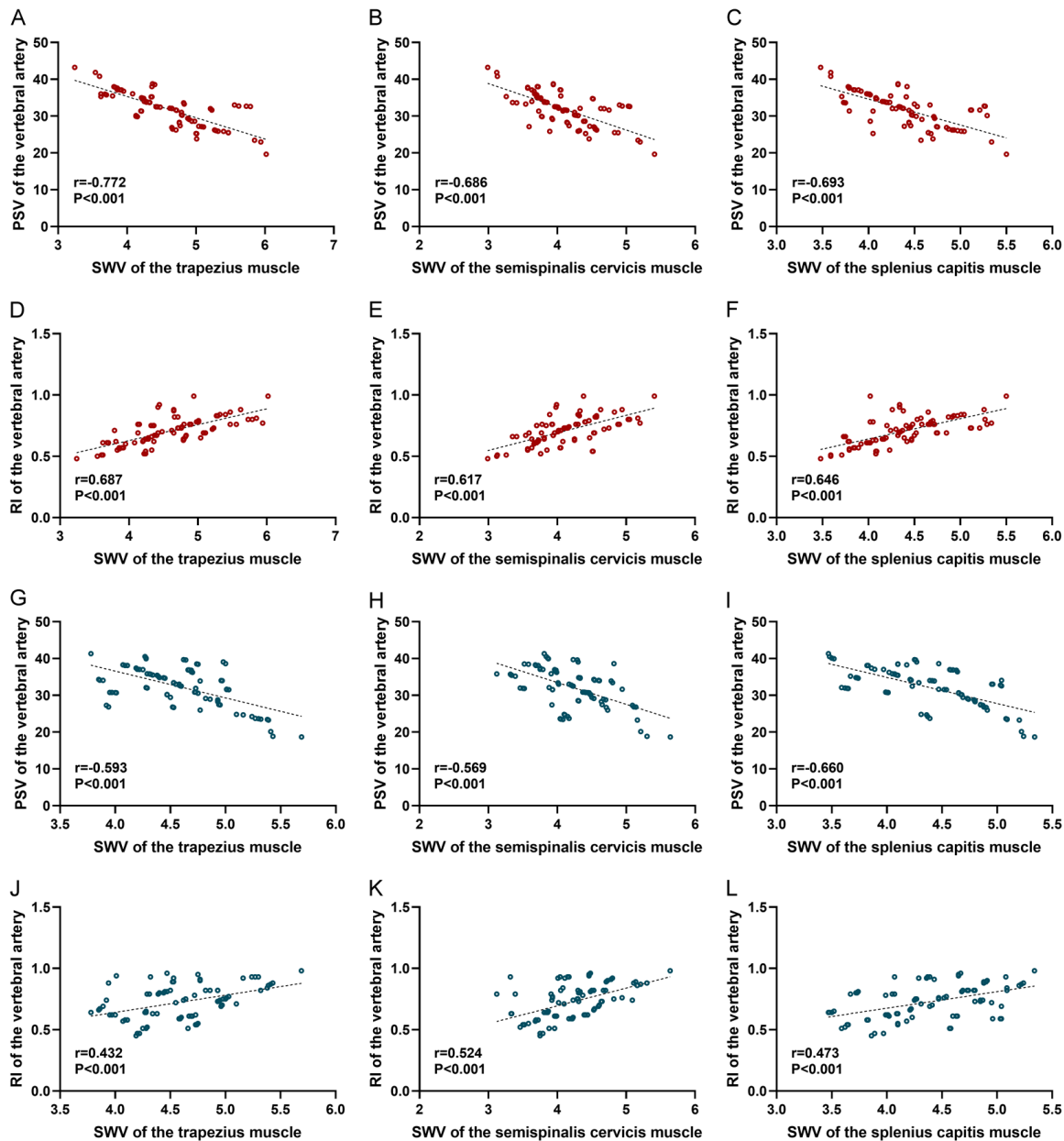


Figure 2. Correlation analysis of neck muscle shear wave velocity with vertebral artery hemodynamic parameters in both groups. For the observation group (A-F): correlations between SWV of the trapezius, semispinalis cervicis, and splenius capitis muscles and ipsilateral vertebral artery PSV and RI. For the control group (G-L): the same correlations for the corresponding muscles. Note: PSV, peak systolic velocity; SWV, shear wave velocity; PI, pulsatility index.

may derive particular benefit from acupuncture. Taken together, these subgroup analyses indicate that acupuncture conferred significant therapeutic benefits across both disease-duration strata and desk-work strata, with all 28 between-group comparisons remaining statistically significant after Bonferroni correction for multiple testing.

Discussion

In this study, we took a systematic look at how well acupuncture works for patients with unilateral pain neck-type cervical spondylosis - specifically, its effects on neck muscle stiffness, cervical spine dysfunction, pain intensity, and local blood flow. We also tried to determine the

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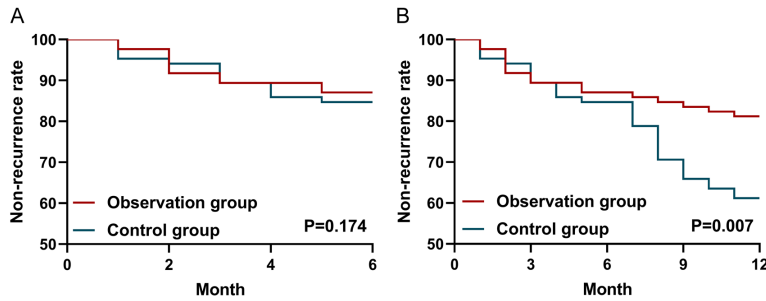


Figure 3. Between-group comparison of disease recurrence using Kaplan-Meier curves. A. 6-month recurrence. B. 12-month recurrence.

possible mechanism using objective imaging data. Acupuncture treatment had more beneficial effects on outcomes with longer-lasting effects than the control treatment regimen, indicating that acupuncture may have certain advantages in the comprehensive intervention of such patients.

According to the global viewpoint, our evidence suggests that acupuncture can indeed alleviate the clinical symptoms and functional status of unilateral pain neck-type cervical spondylosis. The observation group demonstrated superior results in alleviating pain and restoring cervical function compared to the control group. This implies that acupuncture is not just a short-term analgesic but may exert a longer effect by modifying the local pathological environment. A multicenter randomized controlled trial by Chen et al. [14] reported similar findings: the use of optimized acupuncture was significantly effective in alleviating cervical pain and enhancing neck function, whose effects lasted to follow-up. Their findings are in alignment with those of the current study, further advocating the use of acupuncture for cervical spondylosis in clinical practice.

From an evidence-based medicine perspective, systematic reviews have also supported the effectiveness and safety of acupuncture for cervical spondylosis pain. It is shown in literature that acupuncture is more effective than control treatments and helps reduce pain intensity and improves dysfunction with a relatively low overall incidence of adverse reactions [15]. The conclusions drawn from the study provide evidence at a higher level than that used in the clinical efficacy evaluation. It enhances the credibility and extrapolation value of the study.

What were acupuncture's effects on muscle stiffness? We used shear wave elastography to obtain objective shear wave velocity readings from several muscle groups around the neck. Before initiation of treatment, both groups had a comparable level of SWV. The observation group experienced a substantial decline in SWV in various muscles following treatment compared to

the control group. In fact, acupuncture may help lessen hardness of the muscles and decrease stiffness. Compared with palpation or subjective scores, the values obtained from shear wave elastography can better reflect the changes of the muscle's mechanical properties, allowing for a more objective and stable evaluation of efficacy. Moreover, this technique may assist in demonstrating the actual influence of acupuncture on the soft tissue condition [16-18].

According to a possible mechanism, long-term muscle strain or spasms of the neck is one of the important pathological bases of one-sided painful neck-type cervical spondylosis [19]. In other words, acupuncture stimulation may work by ameliorating the contraction status of the muscle fiber and the elasticity of the tissue by regulating local neuromuscular excitability to reduce abnormal tension and restore mechanical properties [20]. Animal studies show that acupuncture may alleviate pain through modulation of the inflammatory response and glial cell activation in cervical spondylosis [21]. Furthermore, recent basic research has begun to elucidate the molecular pathways underlying acupuncture's effects on cervical muscle pathology. In a rabbit model of cervical spondylosis, pestle needle therapy (a derivative modality of acupuncture) was shown to inhibit apoptosis and promote autophagy of posterior cervical muscle cells, while alleviating inflammation (reductions in IL-1 β , IL-6, and TNF- α) and fibrosis injury through inhibition of the PI3K/AKT/mTOR signaling pathway [22]. These findings provide mechanistic evidence that acupuncture-like stimulation can directly modulate the inflammatory microenvironment and cellular homeostasis in neck muscles, offering a plausible molecular basis for the reductions in mus-

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Table 6. Improvement of key indicators after treatment by clinical subgroup

Group	Subgroup	n	Trapezius SWV Change (m/s)	Semispinalis Cervicis SWV Change (m/s)	Splenius Capitis SWV Change (m/s)	NDI Change	VAS Change	PSV Change (cm/s)	RI Change
Observation Group	Disease duration ≤ 6 months	29	-2.31±0.41	-1.76±0.39	-1.47±0.33	-21.05±2.18	-4.21±1.02	11.32±3.21	-0.15±0.07
Control Group	Disease duration ≤ 6 months	32	-1.58±0.38	-1.11±0.36	-0.95±0.30	-16.34±2.05	-2.73±0.94	6.12±2.98	-0.10±0.05
t			7.217	6.769	6.447	8.695	5.898	6.561	3.233
P			< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002
Observation Group	Disease duration > 6 months	56	-2.02±0.36	-1.58±0.34	-1.31±0.29	-18.76±2.01	-3.67±0.98	9.45±2.84	-0.13±0.05
Control Group	Disease duration > 6 months	53	-1.41±0.35	-0.98±0.31	-0.86±0.27	-14.92±1.87	-2.38±0.88	5.21±2.63	-0.09±0.04
t			8.962	9.611	8.373	10.312	7.217	8.075	4.596
P			< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Observation Group	Desk work ≥ 6 h/d	57	-2.28±0.39	-1.72±0.37	-1.45±0.32	-20.84±2.16	-4.12±1.01	10.98±3.05	-0.15±0.06
Control Group	Desk work ≥ 6 h/d	54	-1.52±0.36	-1.05±0.34	-0.92±0.29	-15.87±2.03	-2.61±0.93	5.89±2.91	-0.09±0.04
t			10.652	9.918	9.127	12.476	8.181	8.986	6.164
P			< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Observation Group	Desk work < 6 h/d	28	-2.05±0.35	-1.51±0.33	-1.28±0.28	-18.67±1.94	-3.61±0.95	9.12±2.76	-0.13±0.05
Control Group	Desk work < 6 h/d	31	-1.46±0.33	-0.96±0.30	-0.84±0.26	-15.02±1.85	-2.41±0.87	5.44±2.48	-0.08±0.04
t			6.663	6.706	6.259	7.395	5.065	5.395	4.260
P			< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Note: Data are presented as mean ± SD of pre-to-post treatment change scores. Between-group comparisons within each subgroup were performed using independent-samples t-tests. SWV, shear wave velocity; NDI, Neck Disability Index; VAS, visual analogue scale; PSV, peak systolic velocity; RI, resistance index. *P* values were adjusted using the Bonferroni correction for seven outcome comparisons within each subgroup (adjusted $\alpha = 0.05/7 \approx 0.007$). All reported *P* values remained statistically significant after correction.

cle stiffness observed clinically. While the findings of animal-based studies don't apply directly to clinical findings, they provide important reference for identifying acupuncture's mechanism of pain relief and improved tissue status.

Further analysis discovered a positive correlation between improvements of neck muscle stiffness with the improvement of cervical spine function and pain. In this study, the decline in SWV of neck muscles of patients suggested an improvement of cervical spine dysfunction and pain level concurrently. The results indicate that relieving muscle stiffness can reduce abnormal traction on the cervical facet joints, ligaments, and adjacent soft tissues, resulting in a decrease in the activity of sensory receptors that signal pain and a return to normal pattern of movement of the cervical spine. At the same time, pain relief may also improve patients' tolerance and compliance with functional exercises, further promoting functional recovery and forming a positive cycle.

In terms of hemodynamics, this study observed that the vertebral artery hemodynamic parameters were significantly improved after acupuncture treatment. Compared with the control group, the peak systolic velocity of the vertebral artery in the observation group increased and the resistance index decreased, suggesting that the local blood perfusion status was improved. Previous studies have suggested that tension, hypertrophy, or spasm of the superficial and deep neck muscles can exert a certain external mechanical effect on the vertebral artery and its branches, thereby changing the hemodynamic state [23, 24]. The results of this study suggest that acupuncture may indirectly improve the external compression on blood vessels by relieving neck muscle stiffness, creating conditions for the recovery of local hemodynamics.

The results of correlation analysis further support the above speculation. The present study concluded that there were significant correlations between the SWV of several neck muscles and vertebral artery hemodynamic parameters, inferring a close relationship between the degree of muscle stiffness and local blood flow restriction. The discovery lends objective backing for the muscle-vascular interaction from imagery and functional perspectives. Also, it offers theory support for acupuncture to

improve local circulation by regulating muscle status as a starting point.

From a neurohumoral perspective, emerging evidence suggests that acupuncture may also modulate vasoactive substances to improve vertebral artery hemodynamics. Wang et al. demonstrated that modified acupuncture at Renying (ST 9) significantly reduced plasma concentrations of neuropeptide Y (NPY) and urotensin II (Ull), two potent vasoconstrictor peptides, in patients with cervical spondylosis of vertebral artery type, accompanied by marked improvements in peak systolic velocity of the vertebral and basilar arteries [25]. NPY is a sympathetic co-transmitter known to induce prolonged vasoconstriction, while Ull is among the most potent mammalian vasoconstrictors identified to date. The reduction in these vasoactive peptides following acupuncture provides a plausible humoral mechanism linking acupuncture-induced relief of neck muscle stiffness to the restoration of vertebral artery blood flow observed in the present study. Furthermore, in a rat model of cervical spondylosis radiculopathy, acupuncture was found to down-regulate the phosphorylation of p38 and ERK mitogen-activated protein kinases (MAPKs), reduce microglial activation, and decrease monocyte chemoattractant protein-1 (MCP-1) levels in the spinal cord, thereby attenuating local neuroinflammation [21]. These converging lines of evidence from both vascular and neural mechanistic studies support a multi-pathway model in which acupuncture simultaneously targets muscle inflammation, vascular tone regulation, and neuroinflammatory signaling to produce its therapeutic effects.

Although no significant difference in recurrence was seen between the two groups in the short term, as follow-up progressed the observation group's recurrence rate gradually became lower than that of the control group. This suggests that acupuncture has certain advantages in lowering mid- to long-term recurrence risk. This result suggests that acupuncture may not only relieve short-term symptoms but also help improve the underlying pathological state, thereby reducing the risk of recurrent disease. As reported by previous studies, acupuncture's effects on cervical spondylosis symptoms often show some durability once improvement occurs [14]. This matches the follow-up outcomes of the present study.

Upon examination, safety proved that adverse effects through acupuncture are rare. Most of the rare side effects which occurred were mild and transient. Thus, they did not modify treatment or the eventual outcomes of patients. The findings from the systematic reviews similarly indicate that acupuncture possesses good safety for the treatment of cervical spondylosis [15] and that it has certain advantages in tolerance and safety when compared to long-term drug treatment, providing a realistic basis for the clinical promotion and application of acupuncture.

Several limitations should be noted. First, this was a single-center retrospective cohort study; although propensity score matching was used to balance baseline covariates, unmeasured confounding from the non-randomized design and the absence of blinding for both patients and assessors may have introduced selection and expectation biases, potentially inflating subjective outcomes such as NDI and VAS scores. The lack of a sham acupuncture control group further limits the ability to isolate the specific effects of acupuncture from non-specific placebo effects; sham-controlled designs such as non-penetrating placebo needles or needling at non-acupoint sites are essential for isolating the true therapeutic component of acupuncture. Furthermore, outcome assessors who were aware of group allocation may have introduced ascertainment bias during follow-up assessments. Second, cervical spine X-ray evaluation was qualitative and unquantified, limiting the objectivity and reproducibility of imaging findings. Third, the inclusion of only acute-stage, unilateral-pain patients aged 18-60 years restricts generalizability to chronic, bilateral, or complicated cervical spondylosis populations. Additionally, the modest sample size after matching and the 12-month follow-up duration may still be insufficient to fully capture long-term efficacy or rare adverse events; extended follow-up of 24-36 months is warranted in future investigations. Fourth, although subgroup analyses by disease duration and desk-work history were performed, no a priori stratified intervention protocol was designed that tailors acupuncture frequency, point selection, or treatment duration to disease stage and occupational exposure, thereby limiting the translation of these findings into individualized clinical decision-making. Fifth,

this study did not include cellular or animal experiments to directly elucidate the molecular pathways through which acupuncture regulates cervical muscle tension and vertebral artery blood flow. While existing basic research suggests potential involvement of the PI3K/AKT/mTOR, MAPK, and NPY/UIL signaling pathways in acupuncture's effects on myofascial inflammation, vascular tone, and neuro inflammation [22, 25], direct mechanistic evidence from integrative clinical-basic translational studies remains lacking. Future multi-center, prospective, sham-controlled randomized trials with blinded assessment, quantitative imaging, extended follow-up, parallel mechanistic studies (including biomarker analysis and, where feasible, animal model validation), and pre-specified stratified intervention protocols are warranted to validate and extend these findings.

In summary, this research indicates that acupuncture can significantly enhance neck muscle stiffness, pain intensity, cervical spine function, and local hemodynamics in individuals with unilateral pain neck-type cervical spondylosis. The treatment is safe and effective with a certain degree of durability deserves greater clinical application and dissemination.

Disclosure of conflict of interest

None.

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