Observational Study

Medicine

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Impact of acupuncture combined with ganglioside therapy on serum inflammatory cytokine levels in acute cervical spinal cord injury without fracture or dislocation

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Abstract

This study aims to investigate the effect of acupuncture combined with gangliosides on serum inflammatory cytokine levels in patients with non-fracture dislocation-type acute cervical spinal cord injury (SCI). A total of 160 patients with non-fracture dislocation-type acute cervical SCI admitted to our orthopedic ward were assigned into 4 groups (n = 40 each): control group (C), ganglioside group (G), acupuncture group (A), and combined treatment group (J). All patients received routine methylprednisolone sodium succinate pulse therapy. Group C underwent standard treatment; Group G received additional ganglioside therapy; Group A received acupuncture; and Group J was treated with both acupuncture and gangliosides. Clinical outcomes were assessed through spinal cord function scores, therapeutic efficacy, American Spinal Injury Association grades, Visual Analogue Scale scores, quality of life, somatosensory evoked potentials, and serum levels of tumor necrosis factor (TNF)-α, interleukin (IL)-1β, IL-6, and IL-8. After treatment, Group J showed significantly higher spinal cord function scores and overall efficacy compared with the other groups ($P < .05$). The American Spinal Injury Association grade in Group J was markedly improved ($P < .05$). Visual Analogue Scale scores were lowest in Group J (1.4 ± 0.5, $P < .05$). Quality of life scores across all domains were significantly higher in Group J ($P < .05$). The somatosensory evoked potentials inter-peak latency in Group J was also notably shorter than in the other groups ($P < .05$). Moreover, serum TNF-α, IL-1β, IL-6, and IL-8 levels were most significantly reduced in Group J ($P < .05$). Acupuncture combined with ganglioside therapy significantly decreases serum TNF-α, IL-1β, IL-6, and IL-8 levels in patients with non-fracture dislocation-type acute cervical SCI. This combined treatment demonstrates superior clinical efficacy and functional recovery compared to single therapies.

Abbreviations: ASIA = American Spinal Injury Association, GM1 = monosialoganglioside, IL = interleukin, QoL = quality of life, SCI = spinal cord injury, SEP = somatosensory evoked potential, TNF-α = tumor necrosis factor-α, VAS = Visual Analogue Scale.

Keywords: acupuncture, gangliosides, non-fracture dislocation-type acute cervical SCI, serum inflammatory cytokines, therapeutic efficacy

1. Introduction

Spinal cord injury (SCI) refers to the condition where the spinal cord function is impaired due to external forces acting on the spinal column, such as the cervical, thoracic, or lumbar vertebrae.[1] Acute SCI without fracture or dislocation refers to dislocation that occurs in the cervical spine region, typically resulting from external forces that cause the cervical vertebrae to dislocate and subsequently cause SCI, without considerable vertebral fractures.[2] This type of cervical SCI is not uncommon in clinical practice, accounting for approximately 23% of cervical spinal cord injuries, and its severity and potential complications have garnered considerable attention in the medical field.[3] Researchers have explored the diagnosis and evaluation of SCI without fracture or dislocation in clinical practice. This includes the use of imaging techniques, such as magnetic resonance imaging, to detect the extent and range of SCI, as well as neurofunctional assessment tools to evaluate patients' neurological impairments. These methods contribute to the accurate diagnosis and evaluation of patients with SCI without fracture or dislocation, enabling the development of appropriate treatment plans.[4,5] Conservative treatment is the preferred approach, which includes the application of cervical braces and the use of medications to control inflammation and pain, among other measures.[6,7] Furthermore, some studies have explored the effectiveness of physical therapy, rehabilitation training, and neuroprotective treatments.[8] Although surgical treatment is not common in SCI without

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Fan H, Liu Y, Wu H, Xu W, Li J. Impact of acupuncture combined with ganglioside therapy on serum inflammatory cytokine levels in acute cervical spinal cord injury without fracture or dislocation. Medicine 2026;105:11(e47088).

Received: 9 November 2025 / Received in final form: 22 November 2025 / Accepted: 2 December 2025

http://dx.doi.org/10.1097/MD.0000000000047088

fracture or dislocation, it may be considered in certain specific cases, such as persistent neurological deficits or progressive deterioration of the condition.[3] Overall, research on acute SCI without fracture or dislocation is still in relatively early stages, and further clinical studies are needed to advance our understanding.

Acupuncture is a traditional Chinese medical therapy that involves stimulating specific body points to adjust and balance the body's physiological functions, promoting health and treating diseases.[9] Research has shown that acupuncture treatment can facilitate the recovery of limb function after nerve damage and has positive effects in alleviating pain and accompanying symptoms such as muscle spasms.[10] Patients with cervical SCI often experience pain, and acupuncture can alleviate pain sensations by stimulating peripheral nerves and releasing endogenous analgesic substances.[11] Additionally, studies have demonstrated that acupuncture has a positive impact on neural function recovery. Acupuncture stimulation can improve blood circulation and nerve metabolism, increase the supply of nutrients to the spinal cord region, thereby promoting neural regeneration and functional recovery.[12] Gangliosides, specifically monosialoganglioside (GM1), are a complex lipid molecule found in neural cell membranes and have considerable neuroprotective and reparative effects in treating SCI.[13] Research suggests that GM1 may have a positive impact on neuronal damage and inflammatory response induced by SCI.[14] Some experimental studies and clinical trials have explored the application of GM1 in the treatment of SCI. These studies have found that GM1 may exert its effects through multiple mechanisms, including promoting neural regeneration, inhibiting inflammatory responses, reducing cell death, and improving neural conduction function.[15–17] These effects contribute to reducing the severity of SCI, promoting neural function recovery, and improving the quality of life (QoL) for patients.

Hence, in this study, traditional Chinese acupuncture therapy was combined with gangliosides treatment. By analyzing the levels of inflammatory factors in the serum, such as tumor necrosis factor-α (TNF-α) and interleukin (IL)-1β, we aim to investigate whether this treatment approach can regulate the levels of inflammatory factors in patients with acute non-fracture dislocation-type SCI. This may help alleviate the inflammatory response in patients with acute cervical SCI and potentially promote recovery from the injury, providing insights for the treatment of acute non-fracture dislocation-type SCI in clinical practice.

2. Research methodologies

2.1. Research object

This study was approved by the Ethics Committee of North China Medical & Health Group Xingtai General Hospital. A total of 160 patients with acute non-fracture dislocation-type SCI admitted to our orthopedic ward were selected as the study population. The patients were rolled into 4 groups: control group (C), ganglioside group (G), acupuncture and moxibustion group (A), and joint group (J), with 40 patients in each group. There were neglectable differences in baseline characteristics among the groups ($P > .05$) (Table 1). All patients received routine intravenous methylprednisolone sodium succinate pulse therapy. Group C received conventional treatment, Group G received gangliosides treatment, Group A received acupuncture treatment, and Group J received a combination of acupuncture and gangliosides treatment.

2.2. Inclusion and exclusion criteria

Inclusion criteria: complete clinical data; patients diagnosed with acute non-fracture dislocation-type cervical SCI based on clinical symptoms, signs, and imaging examination results; patients admitted to our hospital for treatment within 24 hours after onset of the disease; informed consent provided, voluntary participation, and signing of the informed consent form.

Exclusion criteria: patients with other severe neurological disorders that affect the assessment of limb function; patients with severe systemic injuries or diseases, such as severe heart disease, pulmonary disease, liver or kidney disease, which may have a notable impact on treatment and recovery; pregnant or lactating women; patients with severe cognitive impairment, mental illness, or psychiatric disorders who are unable to cooperate.

The sample size was estimated a priori based on the primary endpoint of the change in serum TNF-α levels after treatment. According to preliminary data from our department previous studies. With a 2-sided significance level of 0.05 and a power of 0.80 for detecting this difference among 4 groups using 1-way ANOVA, we planned to recruit 40 patients per group, resulting in a total sample size of 160 patients, which was achieved in the present study. The sample size calculation was performed using G*Power (version 3.1). No patients withdrew or were lost to follow-up, and no primary or secondary outcome data were missing. Therefore, the analyses were performed using complete-case data, and no statistical imputation methods were required.

2.3. Therapeutic methodologies

For Group C, intravenous administration of methylprednisolone sodium succinate for injection (0.5 g, Chongqing Huabang Pharmaceutical Co., Ltd., National Medical Products Administration approval number: H201531) was adopted. The initial dose was 30 mg/kg, administered as a 15-minute intravenous bolus therapy. After 45 minutes, a continuous intravenous infusion was started at a rate of 5.4 mg/(kg·h) for 24 hours. During the treatment process, close observation of the patient's condition was carried out. Additionally, routine treatment measures such as skull traction and dehydration were administered according to the patient's condition, as instructed by the physician.

For Group G, in addition to the aforementioned standard treatment, intravenous infusion of gangliosides injection (18 mL/bottle × 10 bottles, Changsha Sailong Gangliosides Technology

Table 1

Basic clinical data of patients.

Group	Male/female (example)	Age (years old)	Causes of damage			
			Falling injury	Crushing injury	Traffic accident	Others
Group C	27/13	52.6 ± 4.8	15	3	8	14
Group G	24/16	50.4 ± 5.3	17	1	5	17
Group A	26/14	51.5 ± 4.2	16	3	5	16
Group J	24/16	52.2 ± 4.7	16	2	7	15
P	.782	.371	.626			

Co., Ltd., approval number: Q/AXSL0002S-2017) was given as an adjunctive therapy. The daily dose was 100 mg for the first 2 to 3 weeks, followed by a maintenance dose of 20 to 40 mg per day. The treatment course lasted for 6 weeks.

For Group A, in addition to the aforementioned standard treatment, acupuncture therapy was administered as an adjunctive therapy. The patient lay prone on the treatment bed, and the acupuncture site was routinely prepared with skin disinfection. A 28-gauge, 1.5-inch disposable acupuncture needle was selected for the procedure. Acupoints along the Governor Vessel in the neck region were selected: Yamen acupoint (midline depression just above the spinous process of the 2nd cervical vertebra) and Dazhui acupoint (depression below the prominent cervical-thoracic junction vertebra). The specific procedure was as follows. Yamen acupoint: the head was slightly tilted forward, and the neck muscles were appropriately relaxed. The needle was inserted slowly at a downward angle for approximately 0.8 inches. Dazhui acupoint: the needle was inserted obliquely upward for approximately 0.8 inches. Sterile acupuncture technique was strictly followed. Once the needles were inserted, the handles of the 2 needles were connected to the positive and negative electrodes of the HuaTuo brand SDZ-II electroacupuncture apparatus (Suzhou Medical Supplies Factory Co., Ltd.). The positive electrode was connected to the Yamen acupoint, while the negative electrode was connected to the Dazhui acupoint. The electrostimulation was set at a frequency of 3 Hz, using intermittent waves with a time interval of approximately 1.5 seconds, and adjusted to the maximum tolerable intensity by the patient. The treatment was administered once daily for half an hour. A total of 15 sessions constituted 1 course of treatment, followed by a 4-day break before initiating the next course. The treatment course consisted of 6 courses.

For Group J, in addition to the treatment measures in Group C, a combination of the treatment approaches utilized in Group G and Group A was applied.

2.4. Evaluation methodologies

2.4.1. Efficacy assessment. The assessment of spinal cord function in cervical spondylosis patients was performed using the 40-point scale (Table 2), to record the scores reflecting the spinal cord function before treatment and at the end of treatment. Cured: improvement rate of score ≥67%, indicating improved or non-worsened compression of the cervical spinal cord, with near-normal restoration of cervical and limb function and minimal impact on normal activities. Improvement: improvement rate of score ≥ 33% and < 67%, indicating improved or non-worsened compression of the cervical spinal cord, with partial relief of clinical symptoms, reduction in neck and shoulder pain, and improvement in cervical and limb function. Not cured: improvement rate of score <33%, indicating worsened compression of the cervical spinal cord, persistent or aggravated neck and shoulder pain, and no improvement or further deterioration in cervical and limb function.

2.4.2. American Spinal Injury Association (ASIA) classification of SCI. The ASIA classification system refers to a set of criteria developed by the ASIA to assess the severity of SCI.[18] It primarily evaluates aspects such as sensory, motor, and autonomic neurological functions in patients and classifies them into 5 levels: A, B, C, D, and E. Level A (complete injury): no sensory or motor function is preserved in the segments below the level of injury, including the sacral segments S4–S5. Level B (incomplete injury): sensory function is preserved below the level of injury, including the sacral segments S4–S5, but no motor function is preserved. Level C (incomplete injury): motor function is preserved below the level of injury, but more than half of key muscles below the level of injury have a muscle grade <3. Level D (incomplete injury): motor function is preserved below the level of injury, and at least half of key muscles below the level of injury have a muscle grade equal to or >3. Level E (normal): sensory and motor functions are normal.

2.4.3. Visual Analog Scale (VAS)[19]. A 10 cm straight line was drawn on a page, with 0 to 10 cm representing scores ranging from 0 to 10. The 0 cm end represented no pain, while the 10 cm end represented severe pain. Patients were instructed to make a mark on the line that corresponds to their perceived level of pain. A score of 0 indicated no pain, scores of 1 to 3 indicated mild pain that was tolerable, scores of 4 to 6 indicated moderate pain that affected sleep but was still tolerable, and scores of 7 to

Table 2

Assessment of spinal cord functional status (40-point method).

Position	Symptom manifestations	Score
Upper limb function (assessed separately for left and right sides, total of 16 points)	Complete loss of function	0
	Can hold objects with difficulty but unable to exert force or perform tasks such as buttoning or writing	2
	Can hold objects and can barely button clothes or write	4
	Can hold objects and button clothes normally, but movement is not agile	6
	Nearly normal function	8
Lower limb function (assessed without distinguishing between left and right, total of 12 points)	Unable to sit or stand independently	0
	Can sit but unable to stand independently	2
	Can stand but unable to move	4
	Can move with assistance from others or using crutches	6
	Can climb stairs with a single crutch or handrail	8
	Can walk independently with a shuffling gait	10
	Nearly normal function	12
Sphincter function (total of 6 points)	Urinary retention or incontinence	0
	Difficulty with urination or defecation or other obstacles	3
	Nearly normal function	6
Limb sensation (assessed separately for upper and lower limbs, total of 4 points)	Experiencing abnormal sensations such as numbness, pain, tightness, or heaviness, or decreased pain perception	0
	Nearly normal function	2
Trunk proprioception (specifically for the trunk region, total of 2 points)	Present	0
	Absent	2

Note: Improvement rate = (posttreatment score − pretreatment score)/(40 score − pretreatment score) × 100%.

10 indicated severe pain that was difficult to tolerate, impacting appetite and sleep.

2.4.4. QoL assessment. The Short Form-36 questionnaire[20] was applied to assess the health status and QoL in 4 dimensions: physical functioning, physiological role functioning, emotional role functioning, and emotional well-being. Each dimension was scored on a scale of 0 to 25, with higher scores indicating better QoL.

2.4.5. Somatosensory evoked potential (SEP) measurement. The SHOEMG-EP-B type evoked potential instrument was utilized to measure SEP wave amplitude and inter-peak latency in all patients before and after treatment.

Examination procedure was as follows. Patients were examined in a double-layer soundproof copper shielded room, with an indoor temperature maintained at approximately 23°C. The patients were in a supine position, and the room was kept in a quiet state. Patients closed their eyes during the examination. Electrodes were placed according to the international 10 to 20 system for cervical SCI assessment of upper limb SEP. First, parameter settings: stimulation time was set at 0.2 ms, analysis time at 100 ms, number of superimpositions at 200 times, skin impedance at 3 KΩ, pulse width at 300 μs, and frequency at 4 times/s. Second, stimulation electrode: bipolar saddle-shaped electrodes were placed at the location of the projection of the median nerve on the palmar side of the forearm, with the negative electrode placed near the proximal end and the positive electrode placed 2 cm away from the wrist crease. The distance between the 2 electrodes was 2 cm. The forearm served as the grounding electrode. Third, recording electrodes: silver plates measuring 1 cm × 1 cm were utilized as recording electrodes, placed at the elbow point, Erb point, C7 spinous process, and the contralateral cortical points C'3 and C'4. Reference electrode was placed at the prefrontal (reference point for SEP) point on the head, with peripheral leads placed on the opposite shoulder. Stimulation intensity: thumb slight twitching was preferred. Fourth, observational indices: the amplitude (Amp) and inter-peak latency of N11 and N20 waves were observed for changes.

2.4.6. Serum inflammatory cytokine (TNF-α, IL-6, IL-8, and IL-1β) level measurement. Peripheral venous blood samples were collected from patients before and after treatment. The blood samples were treated with a 1:9 ratio of 3.8% sodium citrate as an anticoagulant. The samples were centrifuged at 3000 rpm for 5 minutes, and the serum was separated. Enzyme-linked immunosorbent assay was performed to measure the levels of TNF-α, IL-6, IL-8, and IL-1β in the patient's serum. The assay was conducted strictly following the instructions provided in the kit manual.

2.5. Statistics

Data analysis was performed using SPSS 23.0 statistical software. Normality and homogeneity of variances were examined prior to analysis. Descriptive statistics (mean ± standard deviation, $\bar{x} \pm s$) were utilized for continuous variables. The *t* test was employed for group comparisons. One-way analysis of variance was utilized for comparing multiple groups, and post hoc multiple comparisons were conducted using the least substantial difference method. The chi-square test (χ^2 test) was utilized for comparing categorical data. $P < .05$ was considered statistically considerable for all analyses.

3. Results

3.1. Efficacy evaluation results

The results of the spinal cord functional status assessment using the 40-point scoring system showed neglectable differences in functional scores among the 4 groups before treatment ($P > .05$). After treatment, all 4 groups exhibited a notable increase in functional scores ($P < .05$). In Group J, the scores for upper limb function (13.2 ± 2.7), lower limb function (11.2 ± 0.5), sphincter function (5.1 ± 0.7), limb sensation (3.2 ± 0.4), and trunk stability (1.5 ± 0.5) showed the most notable improvement versus the other 3 groups ($P < .05$) (Fig. 1).

There were 14 patients in Group C who were not cured, which was remarkably superior than the other 3 groups ($P < .05$). In Group A, 9 patients were not cured, while in Group G, 7 patients were not cured, showing similar outcomes with neglectable difference between the 2 groups ($P > .05$). In contrast, only 2 patients in Group J were not cured, which was greatly inferior than the other 3 groups ($P < .05$) (Fig. 2).

3.2. Assessment of SCI ASIA grading

According to the ASIA classification results, before treatment, the ASIA grades of the patients in the 4 groups were relatively similar. After treatment, there was a notable improvement in the ASIA grades in all 4 groups ($P < .05$). Moreover, patients in Group J demonstrated a notably better recovery of SCI versus the other 3 groups ($P < .05$) (Table 3).

3.3. VAS scoring results

The VAS scoring results showed that there were neglectable differences in VAS scores among the 4 groups before treatment ($P > .05$). After treatment, the VAS scores markedly decreased in all 4 groups ($P < .05$). Specifically, the VAS scores for Group C, Group A, Group G, and Group J were (3.2 ± 1.1), (2.5 ± 0.8), (2.7 ± 0.6), and (1.4 ± 0.5) respectively. Furthermore, versus the other 3 groups, Group J exhibited the most substantial decrease in VAS scores ($P < .05$) (Fig. 3).

3.4. Assessment of QoL

The results of the QoL assessment showed neglectable differences in the scores of health status, physical function, physiological role, and emotional function among the 4 groups before treatment ($P > .05$). After treatment, there was a notable improvement in the QoL scores in all 4 groups ($P < .05$). Specifically, in Group J, the scores for health status (23.8 ± 1.1), physical function (22.6 ± 1.1), physiological role (23.1 ± 0.6), and emotional function (23.4 ± 1.3) were remarkably superior than those in the other 3 groups ($P < .05$) (Figs. 4–7).

3.5. Detection results of SEPs

The results of SEP testing showed neglectable differences or changes in the amplitudes of N11 and N20 potentials among the 4 groups before and after treatment ($P > .05$) (Fig. 8).

Before treatment, neglectable differences were found in the peak-to-peak latencies of N11 and N20 potentials among the 4 groups ($P > .05$). After treatment, the peak-to-peak latency of N11 potential in Group J was (3.5 ± 0.4) ms, N20 potential was (9.6 ± 0.2) ms; in Group G, N11 potential was (4.6 ± 0.3) ms, N20 potential was (10.3 ± 0.4) ms; in Group A, N11 potential was (4.5 ± 0.3) ms, N20 potential was (10.6 ± 0.5) ms; in Group C, N11 potential was (5.3 ± 0.4) ms, N20 potential was (11.7 ± 0.4) ms. Relative to before treatment, the peak-to-peak latencies of N11 and N20 potentials were markedly shortened in all groups, with Group J showing the most pronounced improvement ($P < .05$) (Fig. 9).

3.6. Detection of serum inflammatory cytokine levels

The results of serum analysis showed inconsiderable differences in the levels of inflammatory cytokines TNF-α,

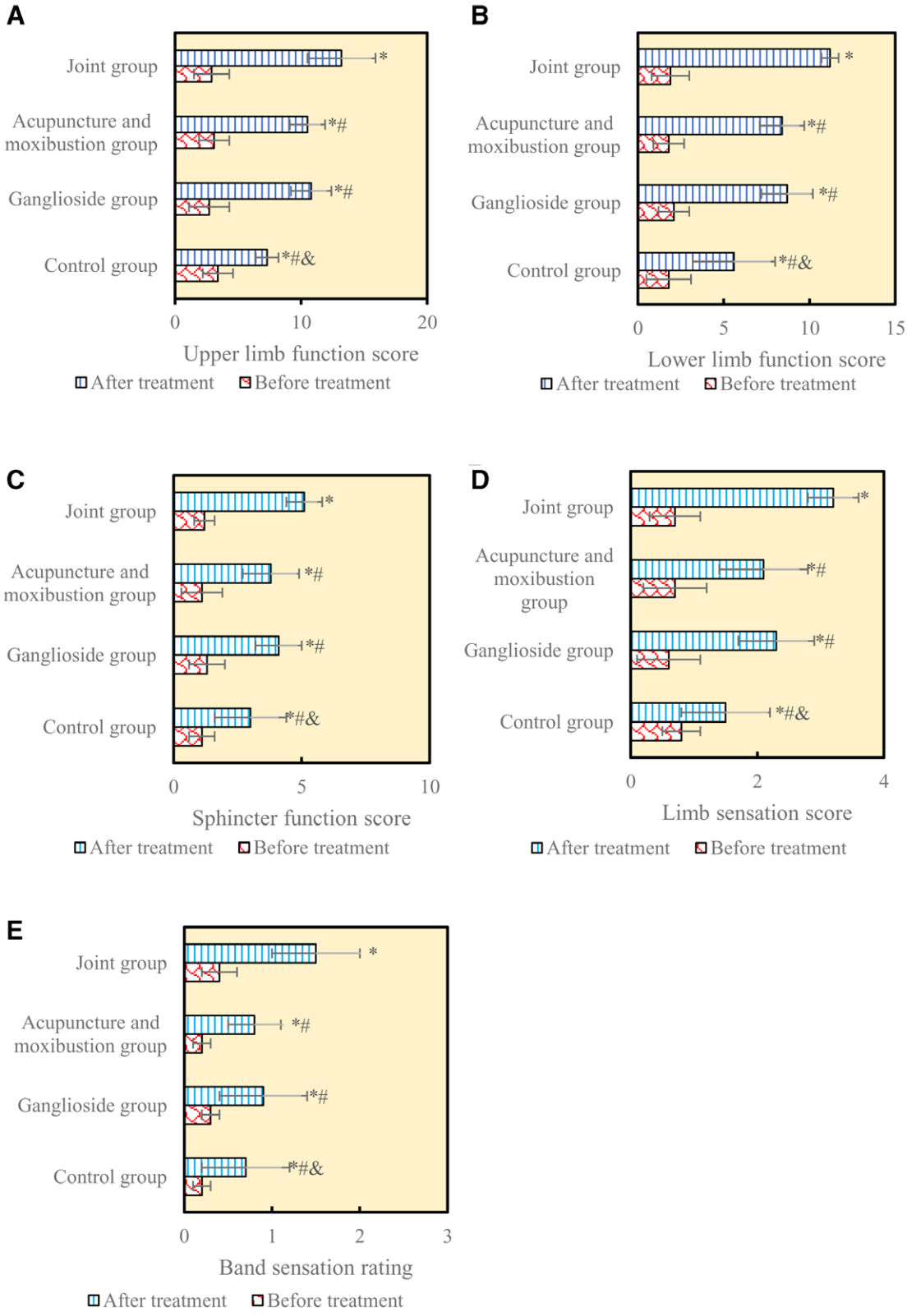

Figure 1. Comparison of spinal cord function status scores in patients (*$P < .05$ vs pretreatment; #$P < .05$ vs Group C; &$P < .05$ vs Groups G and A).

IL-1β, IL-6, and IL-8 among the 4 groups before treatment ($P > .05$). After treatment, the levels of inflammatory cytokines markedly decreased in all groups. Specifically, in Group J, the serum levels of TNF-α were (45.8 ± 8.3) ng/L, IL-1β was (83.2 ± 15.5) ng/L, IL-6 was (0.2 ± 0.1) ng/mL, and IL-8 was (0.3 ± 0.1) ng/mL, which were greatly inferior than those in the other 3 groups ($P < .05$) (Figs. 10–13).

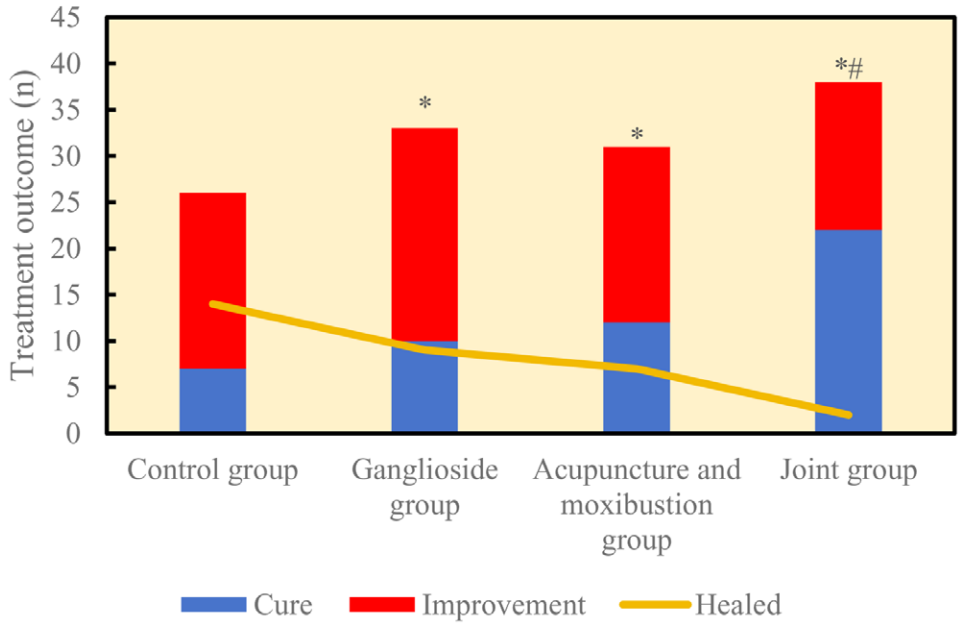

Figure 2. Comparison of treatment efficacy in patients (*P < .05 vs Group C; #P < .05 vs Groups G and A).

Table 3

Comparison of patient ASIA grading evaluation results.

	Group C		Group G		Group A		Group J	
ASIA grade	**Pretreatment**	**Posttreatment**	**Pretreatment**	**Posttreatment**	**Pretreatment**	**Posttreatment**	**Pretreatment**	**Posttreatment**
A	10	4	11	1	9	3	10	0
B	24	11	21	4	22	5	26	5
C	5	18	6	24	7	20	3	11*,†
D	1	5	2	7	2	5	1	16*,†
E	0	2	0	4	0	7*	0	8*,†
P	.036		.017		.015		.004	

ASIA = American Spinal Injury Association.
*P < .05 vs Group C.
†P < .05 vs Groups G and A.

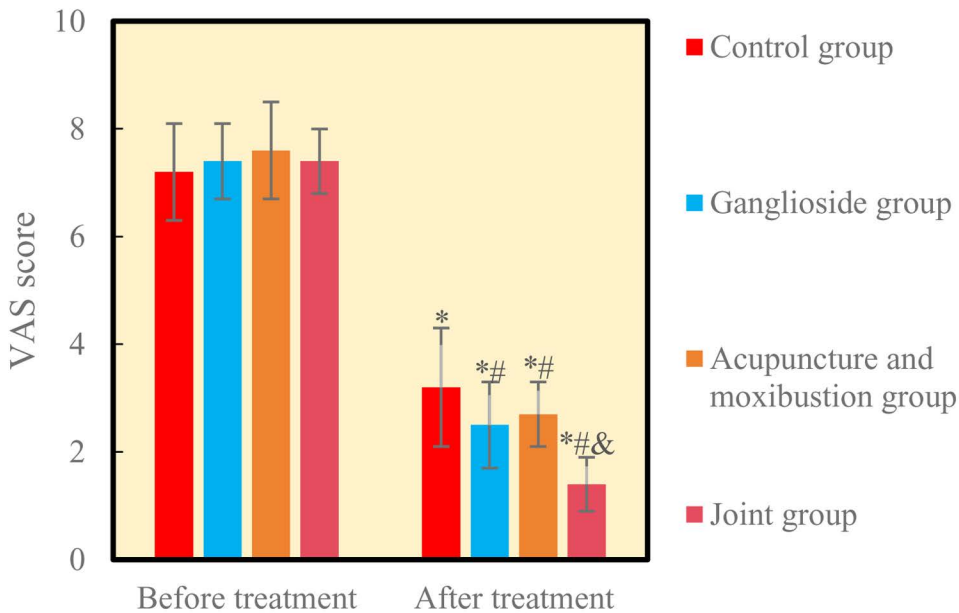

Figure 3. Comparison of VAS scores in patients. (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Group G and A). VAS = Visual Analogue Scale.

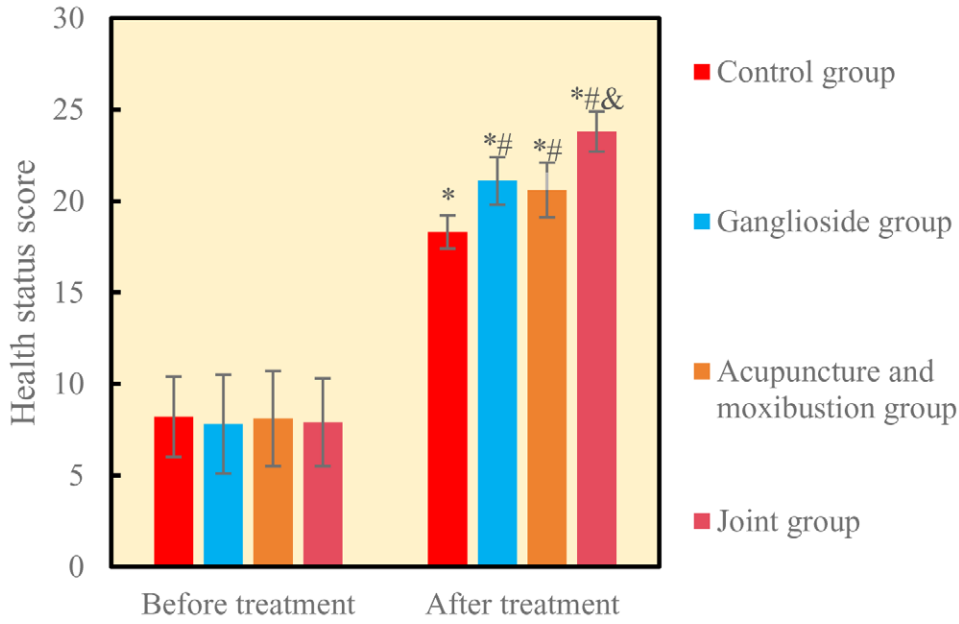

Figure 4. Comparison of health status scores in patients (*$P < .05$ vs pretreatment; #$P < .05$ vs Group C; &$P < .05$ vs Group G and A).

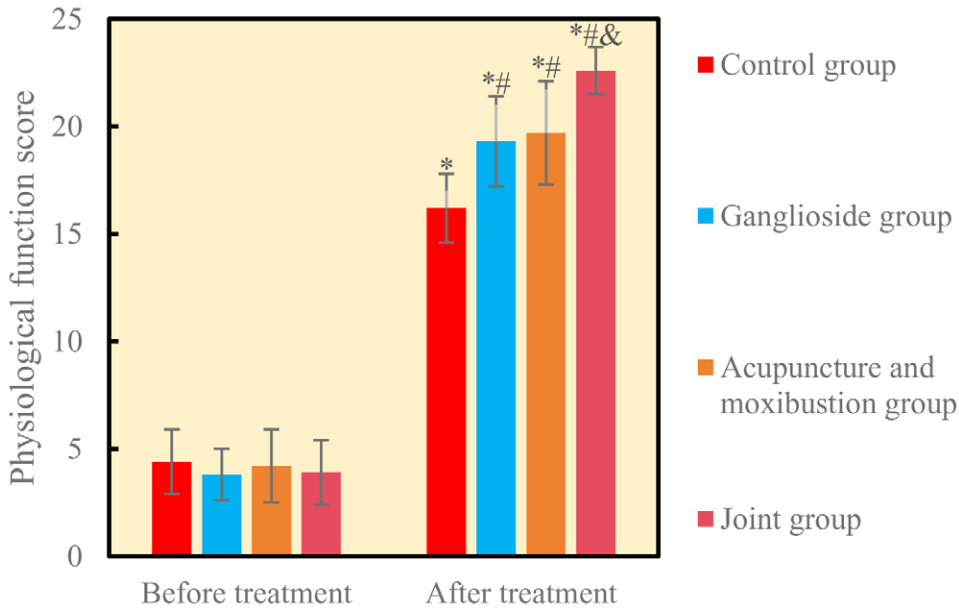

Figure 5. Comparison of physiological function scores in patients (*$P < .05$ vs pretreatment; #$P < .05$ vs Group C; &$P < .05$ vs Groups G and A).

4. Discussion

Acute SCI commonly occurs in cervical spine trauma, including primary injuries (mechanical damage and bleeding) and secondary injuries (edema, inflammatory response, ischemia, cytokines, reperfusion, and their toxic effects on the spinal cord). Severe cases are often accompanied by respiratory failure, requiring prolonged mechanical ventilation.[21] Non-fracture-dislocation-type acute SCI refers to acute SCI without fractures. Early emergency medical intervention and appropriate treatment are crucial, and patients typically require urgent management and comprehensive treatment, including cervical stabilization, reduction of spinal cord compression, pain relief, functional recovery, rehabilitation, and nursing care.[22,23] Pharmacological treatment, as an important therapeutic modality, has been widely adopted to control pain, reduce inflammatory response, and promote neural protection and recovery.[24] Acupuncture, a traditional Chinese medical therapy, involves the insertion of fine needles into specific acupoints to regulate the body's qi and blood flow and balance energy. It is believed to have effects such as pain relief, improved blood circulation, and enhanced neurological function.[25] Gangliosides are a type of neurotrophic factor, and previous studies have shown their considerable role in the survival, development, and maintenance of neuronal function.[26] In this study, traditional Chinese acupuncture therapy was combined with ganglioside injection to treat non-fracture-dislocation-type acute SCI, aiming to explore the feasibility of this treatment approach and its impact on serum inflammatory cytokine levels.

The evaluation of spinal cord function in patients with cervical spondylosis using the 40-point method is a commonly

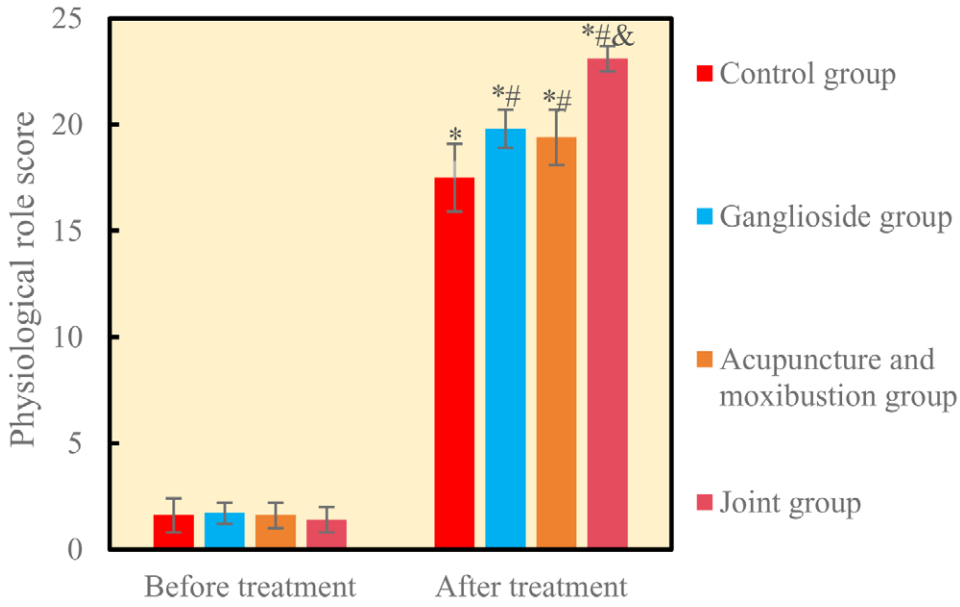

Figure 6. Comparison of physiological role scores in patients (*P < .05 vs pretreatment; #P < .05 vs group C; &P < .05 vs Groups G and A).

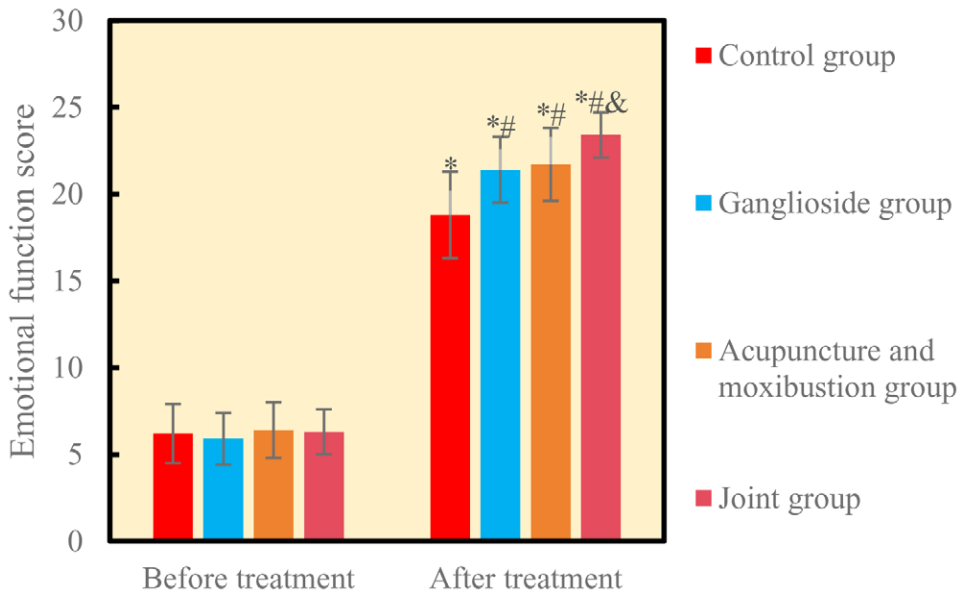

Figure 7. Comparison of emotional function scores in patients (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Groups G and A).

applied assessment method for assessing the spinal cord function in these patients.[24] The ASIA impairment scale for SCI can be utilized to assess the neurological functional status of patients with SCI.[27] The results showed that Group J patients had remarkably superior scores and better treatment outcomes in terms of spinal cord function versus the other 3 groups (P < .05). Furthermore, Group J patients had notably better ASIA impairment scale scores for SCI versus the other 3 groups (P < .05). These findings indicate that compared to conventional or single treatments, the combined therapy of acupuncture and gangliosides can markedly improve the rehabilitation outcomes of patients with SCI, promoting better recovery of spinal cord function and neurological function. In an animal study, gangliosides were utilized to treat SCI in mice, and the results showed that GM1 had therapeutic effects on axonal regeneration in experimental SCI mice.[28] Huang et al[29] integrated recent research on acupuncture treatment for SCI and found that in the past 5 years, the mechanisms of acupuncture in improving the local microenvironment and promoting nerve regeneration have become a new research trend. Ding et al[30] found that acupuncture combined with moxibustion may protect neuronal cells and reduce apoptosis of nerve cells after SCI by regulating the mRNA and protein levels of Shh and Gli-14 in the spinal cord. A case report also demonstrated that a patient with complete SCI and lower extremity paralysis and pelvic organ dysfunction achieved complete bowel control, improved bladder function, and regained the ability to stand with the assistance of acupuncture treatment.[31] These findings are consistent with the results of our study. In summary, the combination of acupuncture and gangliosides can be utilized as an effective treatment for non-fracture dislocation-type SCI.

Previous studies have shown that acupuncture stimulation at specific acupoints can release endogenous analgesic substances, thereby reducing patients' perception of pain.[32–34] In our

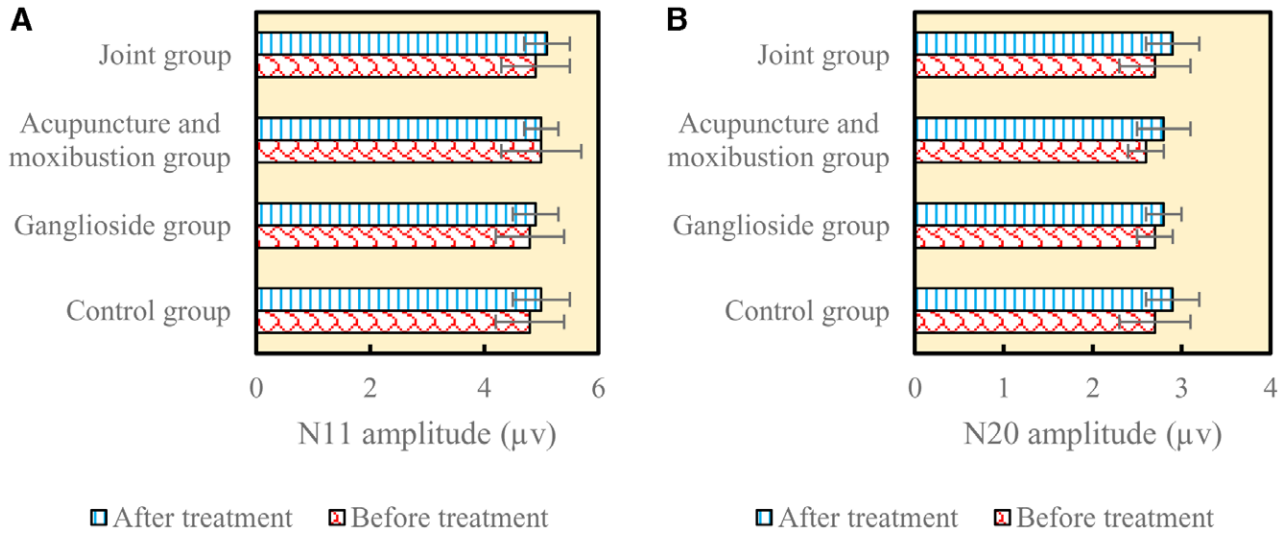

Figure 8. Comparison of SEP wave amplitudes in patients. SEP = somatosensory evoked potential.

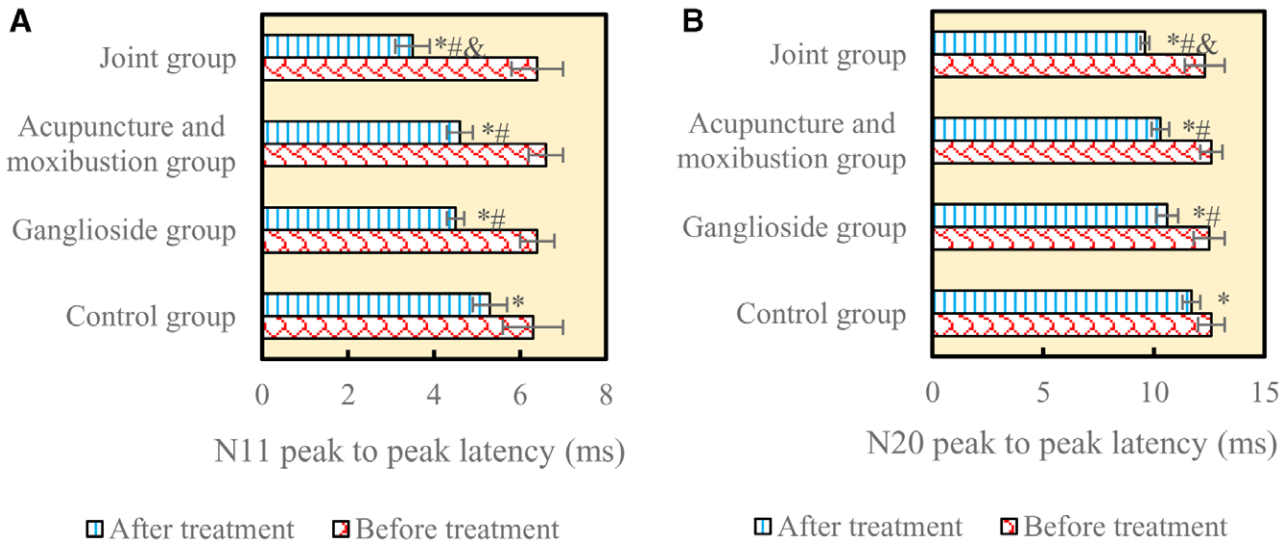

Figure 9. Comparison of SEP inter-peak latency in patients (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Groups G and A). SEP = somatosensory evoked potential.

study, Group J patients showed the most substantial decrease in VAS scores versus the other 3 groups (P < .05). This may be attributed to faster recovery facilitated by the synergistic effect of gangliosides, leading to a subsequent reduction in pain sensation. The assessment of QoL also revealed remarkably superior scores in all dimensions for Group J versus the other 3 groups (P < .05), consistent with the previous findings. Nevertheless, it should be noted that these scores might be influenced by subjective perceptions of the patients and subjective evaluations by the researchers. Additionally, there might be potential confounding factors such as individual differences and treatment compliance, which could introduce biases into the results. Hence, further large-scale studies are needed to confirm these findings. We also performed SPE testing on the patients, with N11 representing the cervical posterior column potential and N20 representing the central posterior body sensory cortex potential. These potentials reflect nerve conduction velocity, and a shorter latency between the peaks indicates increased nerve conduction velocity.[35,36] In this study, the inter-peak latency was markedly shortened in Group J versus the other 3 groups (P < .05). This finding may be attributed to the mechanisms of acupuncture and gangliosides therapy. Acupuncture is believed to modulate the function of the nervous system and promote the recovery of nerve conduction.[37] The application of gangliosides can stimulate the regeneration and repair processes of damaged nerves, promoting the growth of new neuronal processes and providing support and nourishment to injured nerves.[38] The combination of these 2 treatment modalities has a synergistic effect on the restoration of nerve conduction, thereby accelerating the recovery of patients' neurological function.

TNF-α is involved in regulating immune responses and inflammatory processes, and it can induce inflammatory reactions, mediate cell apoptosis, and stimulate the release of cytokines. IL-1β promotes inflammatory reactions, mediates inflammatory cell infiltration, and stimulates the production of cytokines. IL-6 promotes the production of inflammatory mediators and activation of inflammatory cells. IL-8 guides leukocytes to migrate to inflammatory sites, promoting inflammatory responses and the aggregation of immune cells. In this study, these 4 inflammatory cytokines were selected for analysis, and the results showed that serum levels of TNF-α, IL-1β, IL-6, and IL-8 in Group J

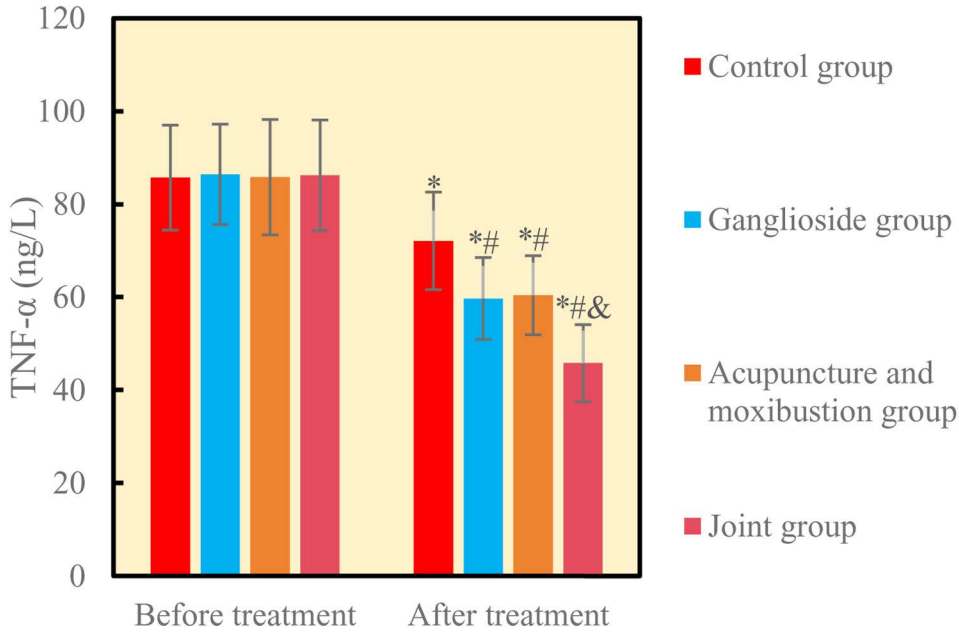

Figure 10. Comparison of serum TNF-α levels in patients (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Groups G and A). TNF-α = tumor necrosis factor-α.

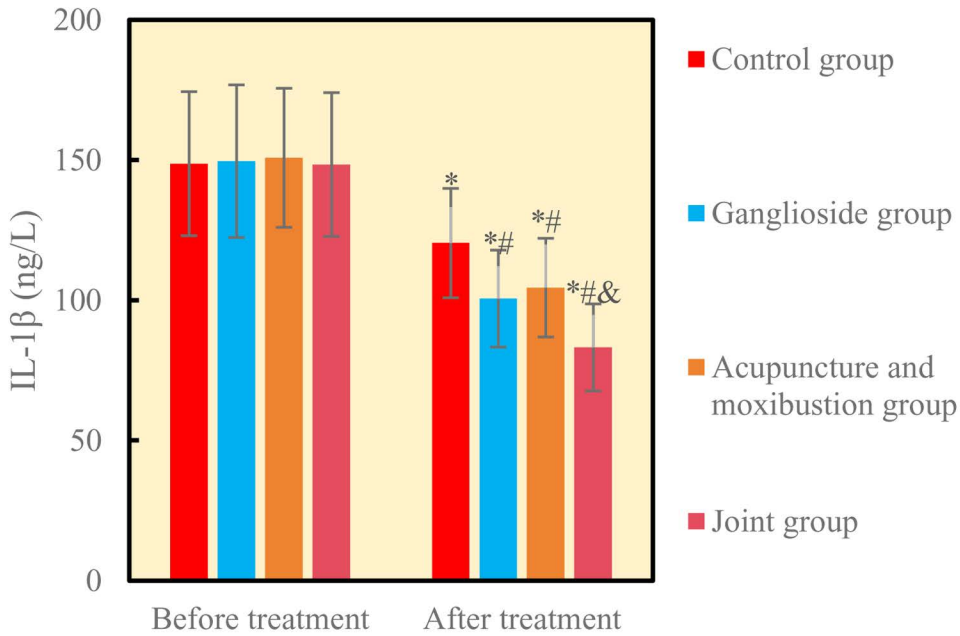

Figure 11. Comparison of serum IL-1β levels in patients (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Groups G and A). IL = interleukin.

were markedly decreased versus the other 3 groups (P < .05). Gusmão et al[39] applied electroacupuncture to treat rats with rheumatoid arthritis and found that the levels of IL-6 and IL-17 in the rats were markedly reduced (P < .05). Another study demonstrated that GM1 decreased inflammatory responses of glial cells both in vitro and in vivo.[40] These anti-inflammatory effects were dependent on the presence of sialic acid residues in the GM1 polysaccharide head group and the lipid tail. Other gangliosides, such as GD3 and GD1, exhibited similar anti-inflammatory effects in in vitro models. Taken together with the results of our study, it can be concluded that the combined application of these 2 treatment methods further enhances the suppression of inflammatory cytokines, leading to better efficacy compared to conventional or single treatments.

In summary, this study suggested that the combination therapy (acupuncture combined with gangliosides treatment) demonstrated favorable efficacy in patients with non-fracture dislocation-type SCI. It not only improved the patients' spinal cord functional status and ASIA grading, but also enhanced their QoL scores and promoted the recovery of nerve conduction velocity. Additionally, the combination therapy inhibited inflammatory reactions and reduced levels of inflammatory cytokines, which may have a positive impact on neuroprotection and repair. Nevertheless, it should be noted that this study had a relatively small sample size and was conducted in a single

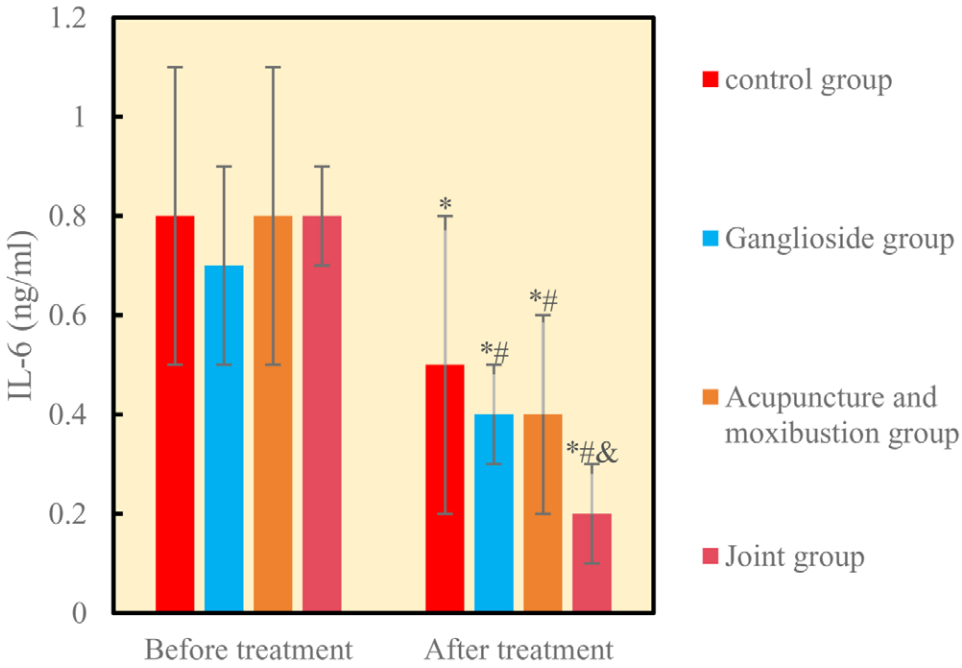

Figure 12. Comparison of serum IL-6 levels in patients (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Groups G and A). IL = interleukin.

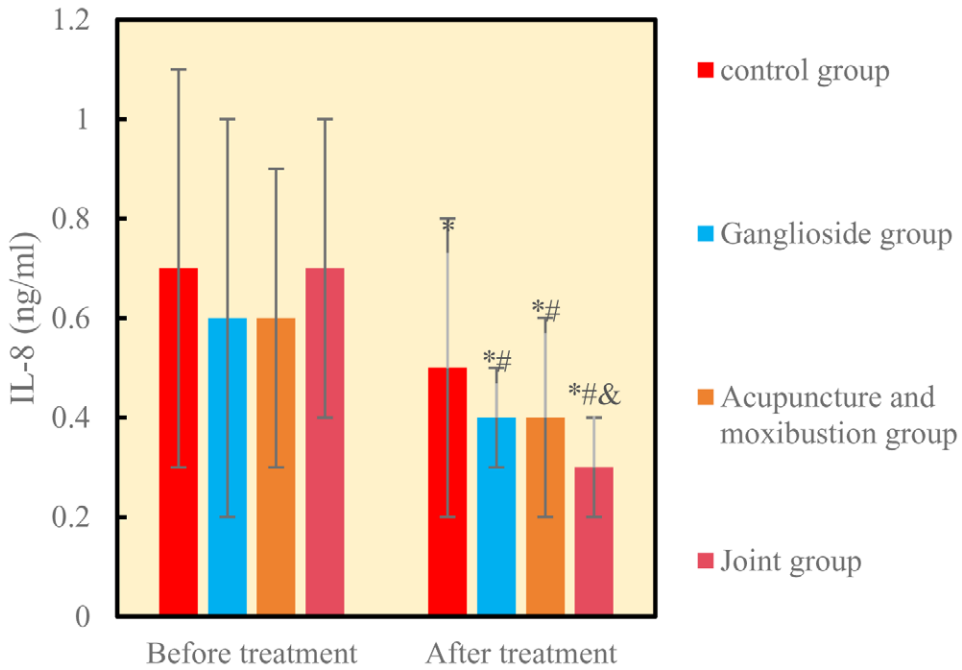

Figure 13. Comparison of serum IL-8 levels in patients (*P < .05 vs pretreatment; #P < .05 vs Group C; &P < .05 vs Group G and A). IL = interleukin.

center, which could introduce certain biases in the research findings. Further large-scale multicenter studies are warranted to ensure the reliability of the results.

5. Conclusion

This study demonstrated that the combination of acupuncture and gangliosides treatment markedly improved spinal cord function, QoL, and treatment outcomes in patients with non-fracture dislocation acute cervical SCI. Relative to single treatments or conventional therapies, the combination therapy effectively alleviated patient pain, improved nerve conduction function, and reduced the expression levels of inflammatory factors in the body. Nevertheless, it should be noted that this study had limitations in terms of sample size and single-center source, which may introduce biases in the research findings. Hence, larger-scale multicenter studies are needed to validate these findings, as well as to further explore the mechanisms and long-term efficacy of the combination therapy.

Author contributions

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Writing – original draft: Huilong Fan, Yang Liu, Jikai Li.
Writing – review & editing: Huilong Fan, Yang Liu, Jikai Li.

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